2nd Planetary CubeSat Science Symposium

Using Rideshare to Launch CubeSats & ESPA S/C

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9/26/2017

Air Force/STP-1

NASA/TESS

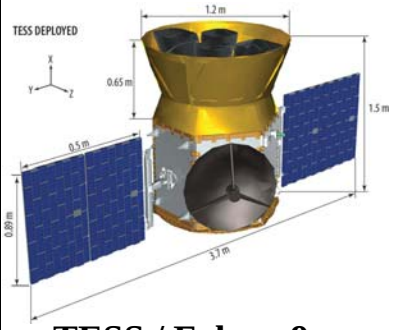
Commercial/SFI

SLS/Block 1B

Rideshare Opportunities Lost and Potential Rideshare Opportunities Lost

DSCOVR / Falcon-9
E-S L1 Orbit

NASA Mission	Launch Date	Orbit	L/V	Excess Mass (kg)
Landsat-8	Feb 2013	SSO	Atlas 5	4400
DSCOVR	Feb 2015	E-S L2	Falcon 9	2500
TDRS-M	Oct 2017	GTO	AV401 (1)	271
TESS	Dec 2017	TL1	Falcon 9	3000
Landsat-9	Dec 2020	SSO	TBD	4400
SWOT	Apr 2021	LEO	Falcon 9	6030
JPSS-2	Jul 2021	SSO	AV401	TBD
Sentinal-6	Dec 2021	SSO	TBD	TBD
TOTAL:				20,601



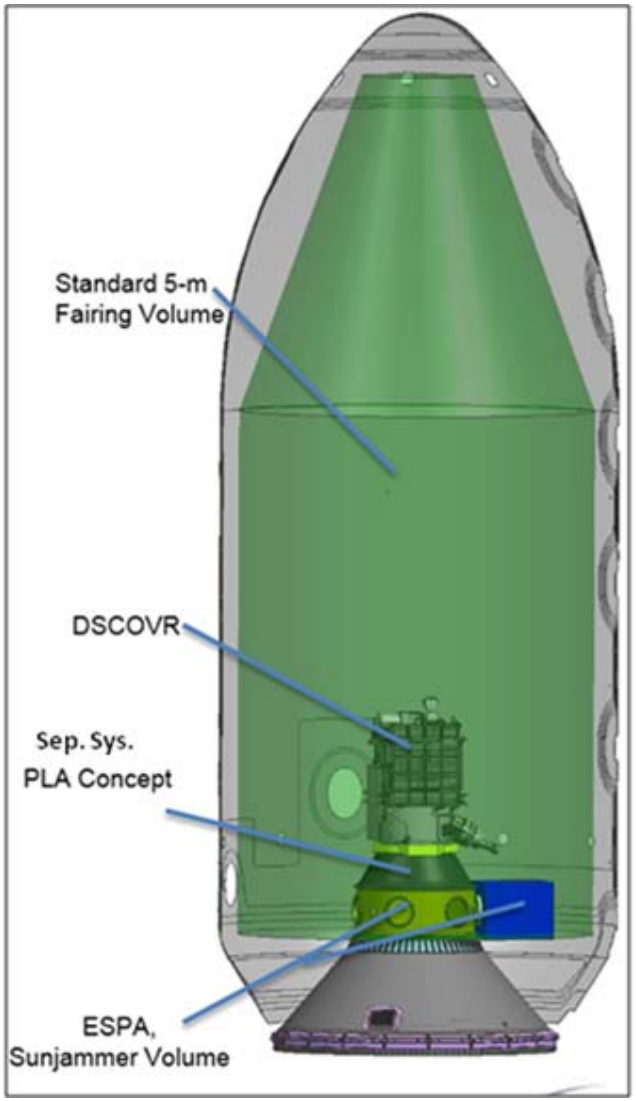
TESS / Falcon 9
TLI orbit

Landsat-8 / Atlas V
Sun-Sync Orbit

Rideshare Adaptor	Mass (kg)	No. of S/C
ESPA Ring	137	6
ESPA Grande Ring	211	4
ESPA w/max s/c mass	1937	6
ESPA Grande w/max s/c	2011	4
Propulsive ESPA	1,500	1 - 7
Propulsive ESPA Grande	2,500	1 - 5

Landsat-9 / TBD LV
~4400 kg excess to polar

Rideshare Poster-child: DSCOVR & TESS



DSCOVR (*February 2015*):
2500 kg of unused mass went to L-1

TESS (*March 2018*):
~3000 kg excess on a TLI orbit

NASA & Air Force Rideshare Opportunities

Year	LEO (mid inc)	LEO (hi inc)	MEO	GEO	Other / TLO
2017					TESS
2018	**STP-2**				EM-1
2019	**RALI**		**GPS III-3**	**STP-3**	
2020		Landsat-9 Sentinel-6 (JPL)	**GPS III-4**		
2021		**STP-S28** SWOT (JPL) JPSS-2	**GPS III-5**	**SBIRS/G5 (GTO)**	EM-2
2022		PACE			EM-3
2023	**STP-S29**				EM-4

Key: **Air Force Missions (bold)** & NASA (non-bold)

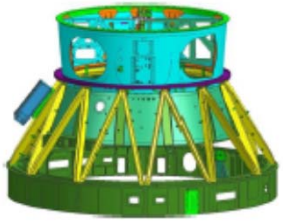
Commercial Rideshare Opportunities

(vendor quad charts & launch details in backup)

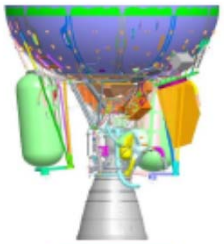
Year	LEO (Low Inc.)	Polar (Hi Inc.)	MEO (1100x185)	GEO (35786x35786)	Other
2017	ET, NR, OA, TV	SF, TV		NR	TV (GTO)
2018	ET, NR, OA, TS, TV	SF, TS, TV	TS	SF, NR, TV, AL	TV (GTO)
2019	TV, NR, OA	SF, TS, TV		SF, NR, TV	TV (GTO), TV (EE)
2020	TV, NR, OA	SF, TV		SF, TV	TV (GTO)
2021	TV, NR, OA	SF, TV		SF, TV	TV (GTO)
2022	TV, NR, OA	SF, TV		TV	TV (GTO)

AL - Adaptive Launch Solutions
ET - Electron
NR - NanoRacks
OA - OrbitalATK
SF - SpaceFlight
TS - TriSept
TV - Tyvcak

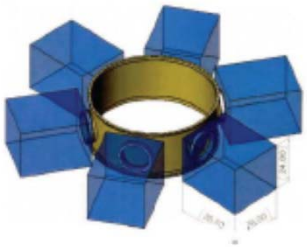
Rideshare Adaptors: Enables a Family of S/C



P-POD
10 kg



ABC
80 kg

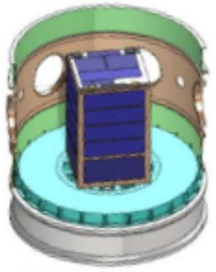


ESPA
200 kg

Rideshare Carrier	Mass Available	Volume Available	S/C Interface
CubeSats	5-10kg	3U-6U	Standard
ABC	80kg	34x20x20	8/15" cir.
ESPA (1 of 6)	~320kg	24x28x38	8/15" cir. & 15" squ.
ESPA Grande (1 of 4)	~450kg	42x46x56 42x46x38	15/24" cir. & 24" squ.
Aquila (A-Deck)	~1,000kg	56-diax60h	24/38" cir.
Propulsive ESPA S/C	~1,500kg	4m-diax24h	PAF
Propulsive ESPA Grande	~2,500kg	5m-diax42h	PAF

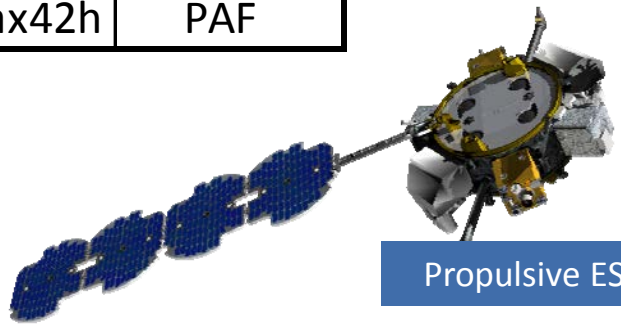
ESPA Grande

~350 kg



A-Deck / Aquila

~1,000 kg

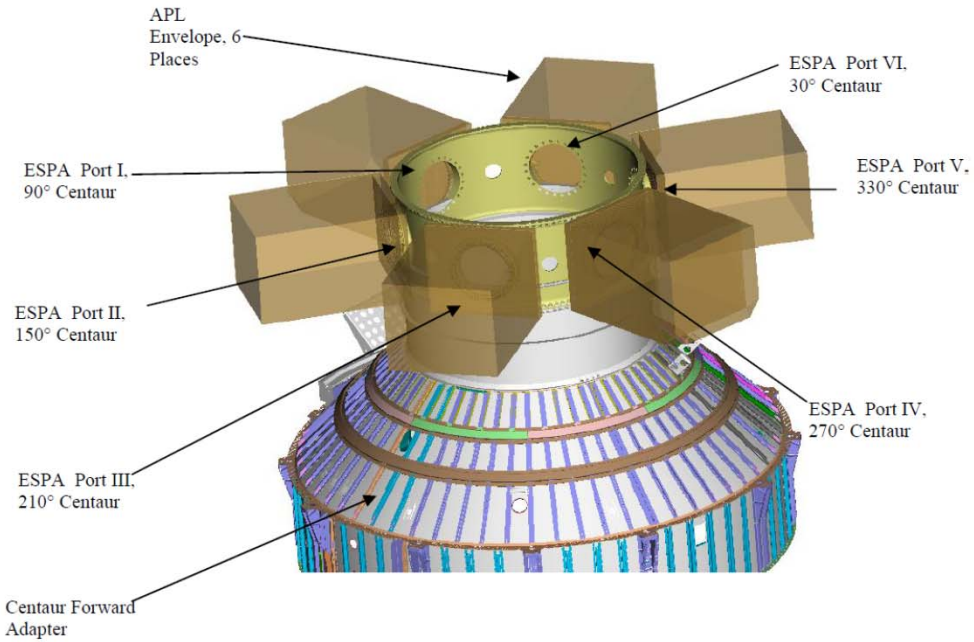


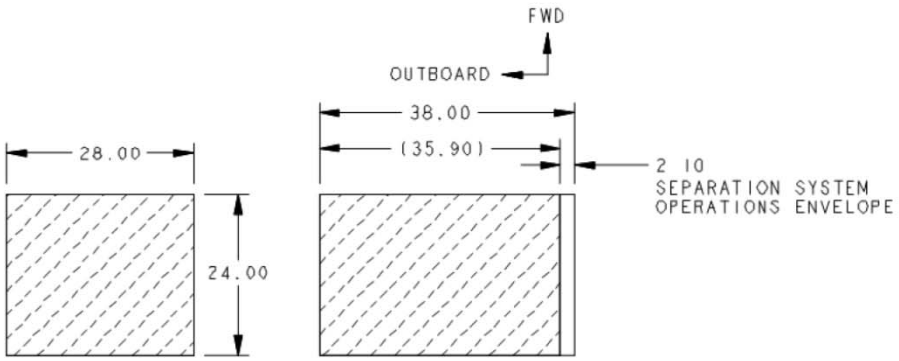
Propulsive ESPA

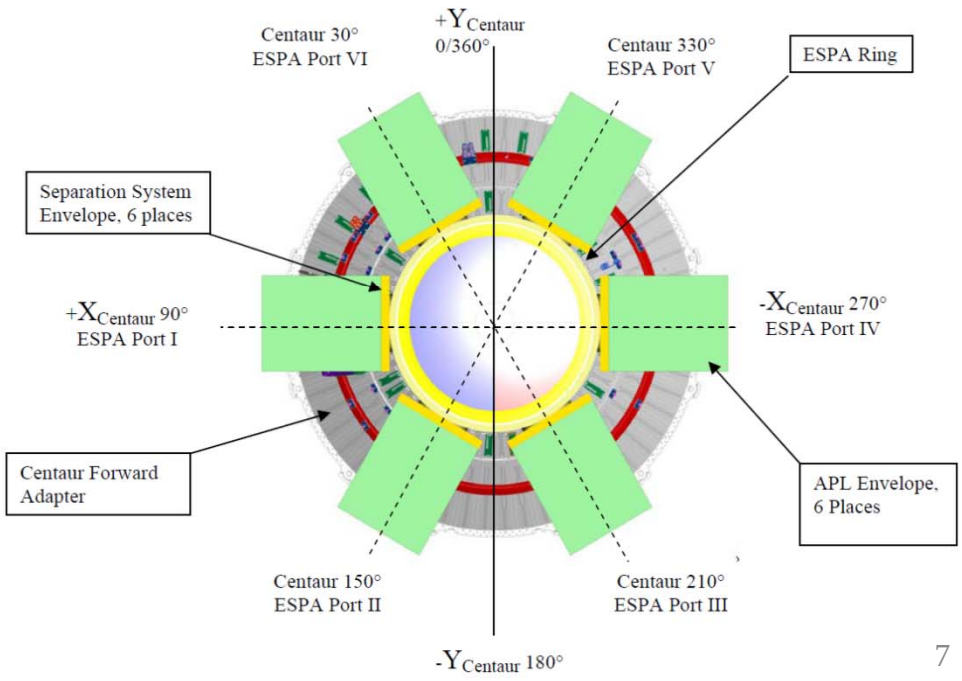
~1,500 kg

a family of spacecraft can reduce costs and improve performance

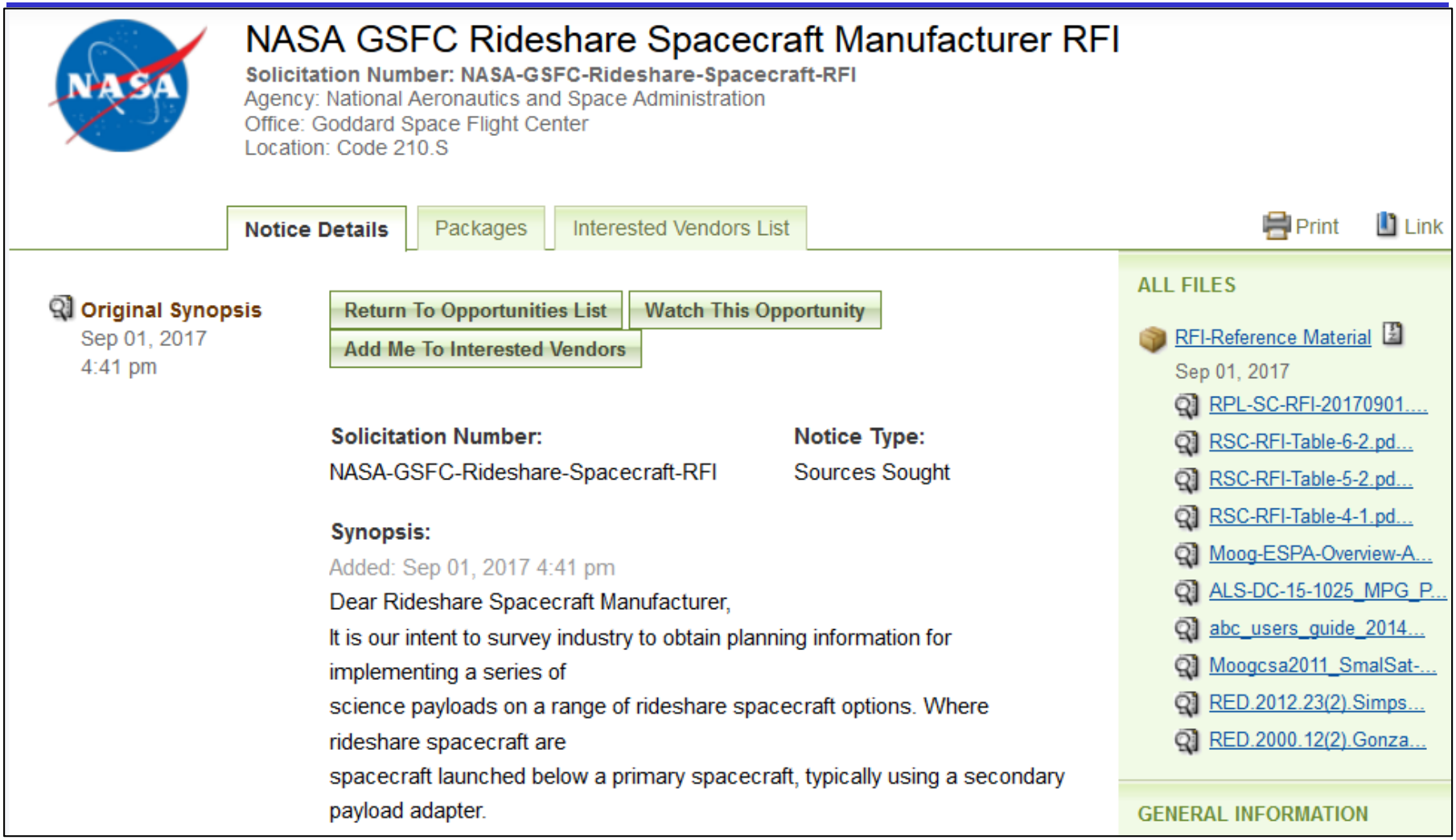
ESPA Mechanical Data







Rideshare Spacecraft RFI
(responses due 10/5/2017)



NASA GSFC Rideshare Spacecraft Manufacturer RFI

Solicitation Number: NASA-GSFC-Rideshare-Spacecraft-RFI
Agency: National Aeronautics and Space Administration
Office: Goddard Space Flight Center
Location: Code 210.S

Notice Details | Packages | Interested Vendors List | Print | Link

Original Synopsis
Sep 01, 2017
4:41 pm

Return To Opportunities List | Watch This Opportunity | Add Me To Interested Vendors

Solicitation Number:
NASA-GSFC-Rideshare-Spacecraft-RFI

Notice Type:
Sources Sought

Synopsis:
Added: Sep 01, 2017 4:41 pm
Dear Rideshare Spacecraft Manufacturer,
It is our intent to survey industry to obtain planning information for implementing a series of
science payloads on a range of rideshare spacecraft options. Where rideshare spacecraft are
spacecraft launched below a primary spacecraft, typically using a secondary payload adapter.

ALL FILES

RFI-Reference Material
Sep 01, 2017
RPL-SC-RFI-20170901....
RSC-RFI-Table-6-2.pd...
RSC-RFI-Table-5-2.pd...
RSC-RFI-Table-4-1.pd...
Moog-ESPA-Overview-A...
ALS-DC-15-1025_MPG_P...
abc_users_guide_2014...
Moogcsa2011_SmalSat-...
RED.2012.23(2).Simps...
RED.2000.12(2).Gonza...

GENERAL INFORMATION

<u>Elements of the RFI</u>: 1) literature review; 2) spacecraft capabilities; 3) instrument accommodation req.; & 4) Com P/L requirements

Rideshare Spacecraft RFI: Collecting Commercial Options

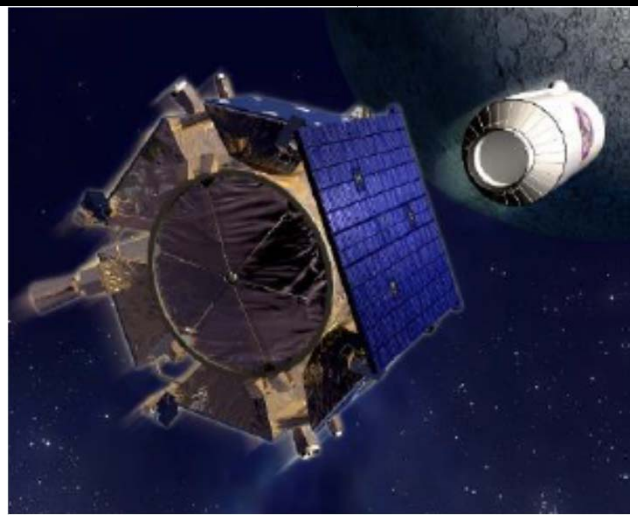
No.	Rideshare Adaptor/Carrier	Vendor / Bus	P/L Mass Capability	P/L Power (OAP/Peak)	Thermal Dissipation	Pointing Control	P/L Mounting Area Avail.	Spacecraft Design Life	Spacecraft Dimensions	Delta-V / Prop System	Available Orbits	TRL / No. on Orbit	Pointing Stability
1.0	ABC Class S/C (~80k)												
2.0	ESPA Class S/C (~320kg)												
3.0	ESPA Grande Class S/C (~450kg)												
4.0	A-Deck Class S/C (~1,000kg)												
5.0	Propulsive ESPA S/C (~1,500kg)												
6.0	Propulsive ESPA Grande (~2,500kg)												

No.	Rideshare Adaptor/Carrier	Vendor / Bus	ooo	P/L Cmd Interface	P/L Data Interface	P/L Power Interface	ROM Cost	Dev. Schedule	Comments
1.0	ABC Class S/C (~80k)								
2.0	ESPA Class S/C (~320kg)								
3.0	ESPA Grande Class S/C (~450kg)								
4.0	A-Deck Class S/C (~1,000kg)								
5.0	Propulsive ESPA S/C (~1,500kg)								
6.0	Propulsive ESPA Grande (~2,500kg)								

Rideshare / ESPA Integration and the lost opportunity of the used rideshare slots

Mission	L/V	Carrier	Launch Date	S/C Capacity	S/C Flown	Empty Slots
STP-1	Atlas 5	ESPA	March 2007	6	4	2
LCROSS	Atlas 5	Propulsive ESPA	June 2009	1	1	0
OG2- 1	Falcon 9	ESPA Grande (2ea)	July 2014	8	6	2
AFSPC-4	Delta IV	ESPA/ANGELS	July 2014	6	1	5
OG2-2	Falcon 9	ESPA Grande (3ea)	December 2015	12	11	1
AFSPC-6	Delta IV	ESPA	July 2016	6	0	6
			Total:	39	23	16

STP-1



LCROSS

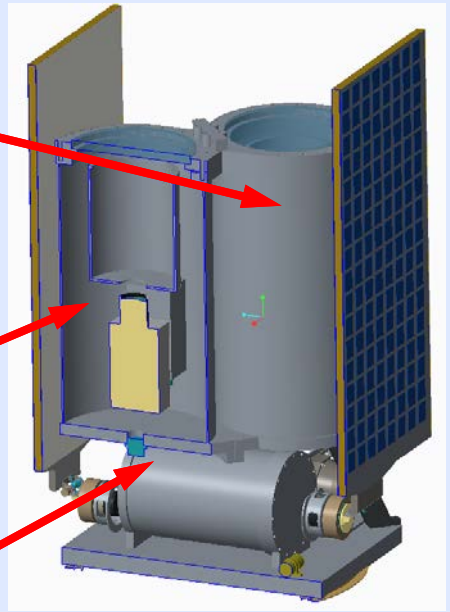
OG2-2

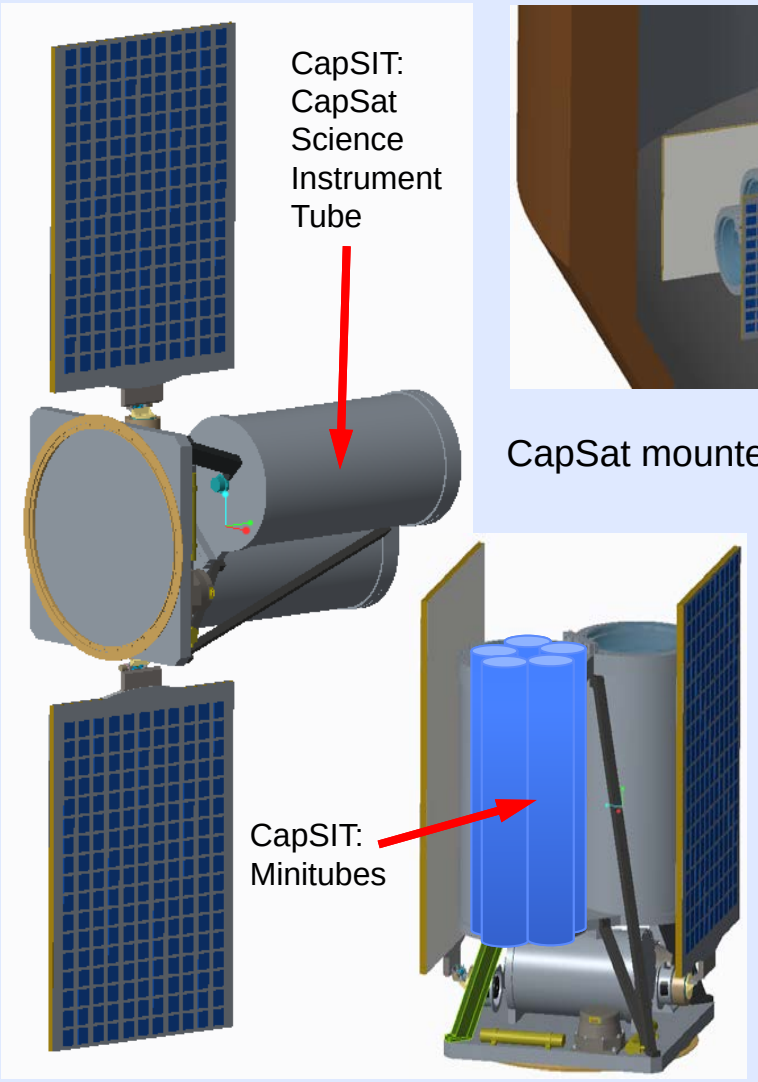
Capsulation Satellite: CapSat

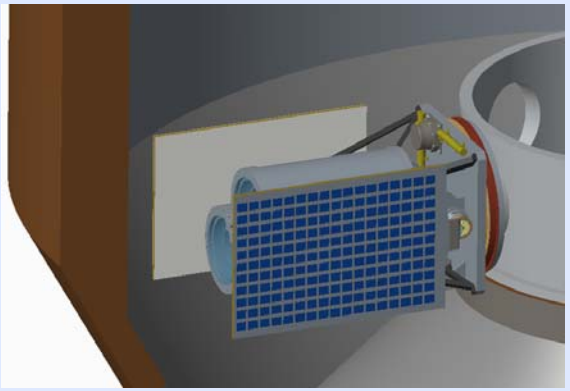
Capsulation Satellite or CapSat **is a low cost, 3 axis stabilized, modularized and standardized spacecraft, based on a pressurized volume with active thermal control allowing ruggedized COTS hardware to be flown reliably in space.**

EELV launch Capacity goes unused in large part do to cost. Typical CubeSat's are still nearly $1M/kg. A single CapSat can provide over 300kg of on-orbit mass at a cost 20 times cheaper; ~$50K/kg.

CapSat achieves this by leveraging proven SmallSat and CubeSat hardware combined with decades of GSFC software heritage in the cFS-Core Flight System and ITOS-Integrated Test & Operations System.







CapSat mounted to a 6 port ESPA

Goddard Space Flight Center

Contact:
EHPD-Explorers and Heliophysics Program Office

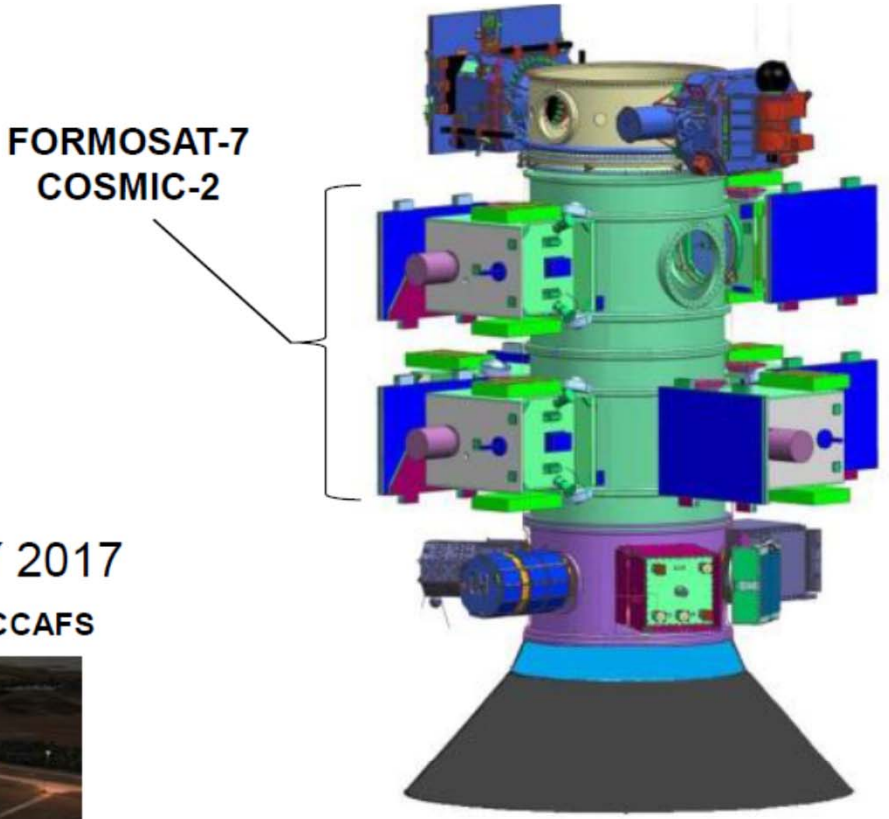
Joe.Burt@nasa.gov

Rideshare Example: COSMIC-2B on STP-2

(A five burn mission delivering multiple payloads into several different orbits)

- Integrated Payload Stack (IPS)
  - Six COSMIC-2 Spacecraft
  - Demonstration and Science Experiment (DSX)
  - Six Auxiliary Payloads (APLs)
  - Dispensers plus ballast
  - Eight PPODs with Twelve Cubesats for LEO
- Falcon Heavy demonstration launch planned for Q4 CY 2016
- COSMIC-2 launch planned for Q1 CY 2017

Concept of Falcon Heavy from Launch Comlex-39A CCAFS



STP-2: multiple payloads, multiple orbits

- Orbit 1: 300 x 720 km at 28.4 deg inc., 1+8 deployed
- Orbit 2: 720 x 720 km at 24 deg inc., 11 deployed
- Orbit 3: 6000 x 12000 km at 45 deg, 1 deployed

SLS CAPABILITY AVAILABILITY

SLS Block 1
As Early As 2019

Provides

Initial Heavy-Lift Capability

Enables

Orion Test

SmallSats to Deep Space

SLS Block 1B Crew
As Early As 2022

Provides

105 t lift capability via Exploration Upper Stage

Co-manifested payload capability in Universal Stage Adapter

Enables

Deep Space Gateway

Larger CubeSat- and ESPA-Class Payloads

SLS Block 1B Cargo
As Early As 2022

Provides

8.4-meter fairings for primary payloads

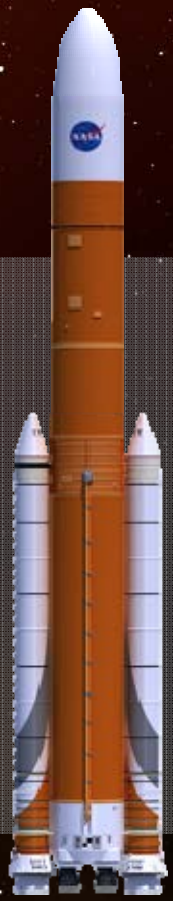
Enables

Europa Clipper/Lander

Deep Space Transport

Ice or Ocean Worlds Missions

Large-Aperture Space Telescopes



SLS Block 2
As Early As 2028

Provides

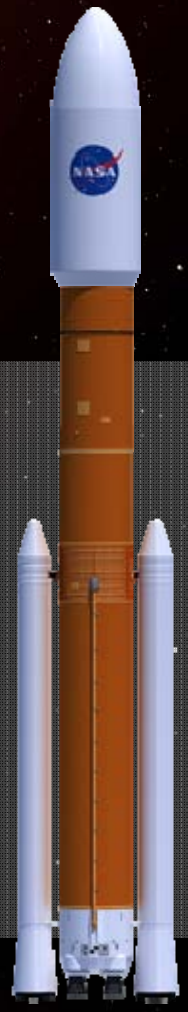
130 t lift capability via advanced boosters

10-meter fairings for primary payloads

Enables

Crewed Mars Orbit Missions

Crewed Mars Surface Missions



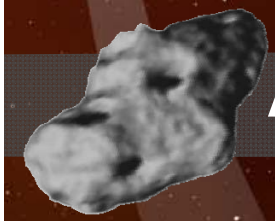
SLS SPACE LAUNCH SYSTEM

www.nasa.gov/sls

EM-1 Secondary Payload Manifest

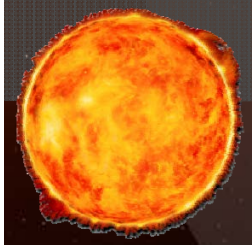
Moon

- Lunar Flashlight (NASA)
- Lunar IceCube (Morehead State University)
- LunaH-Map (Arizona State University)
- OMOTENASHI (JAXA)



Asteroid

- NEA Scout (NASA)



Sun

- CuSP (Southwest Research Institute)

Earth

- EQUULEUS (JAXA)
- LunIR (Lockheed Martin)

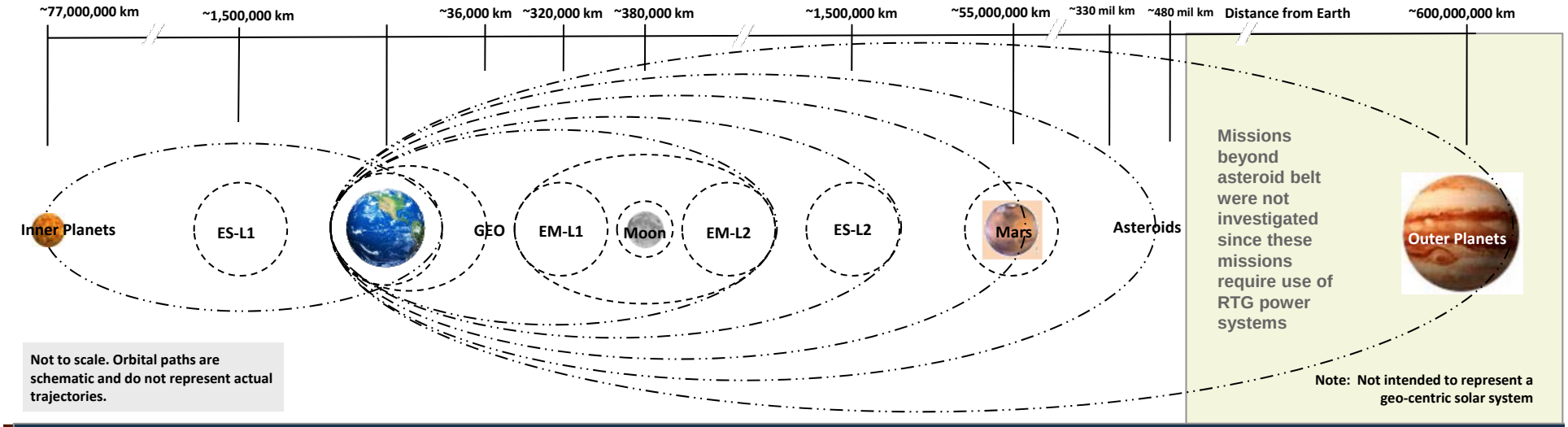
And Beyond

- Biosentinel (NASA)
- ArgoMoon (ESA/ASI)
- Cislunar Explorers (Cornell University)
- CU^3 (University of Colorado Boulder)
- Team Miles (Fluid & Reason)

A SLS Propulsive Payload Ring Approach

- **SLS has the capability to deliver payloads Beyond Earth Orbit using a Propulsive Payload Ring offering ESPA-like interfaces**
- **Initial Performance Capability using ESPA as a benchmark**
  - EELV Secondary Payload Adapter (ESPA) is standard payload adapter ring used for launching ride-share payloads on Evolved Expendable Launch Vehicle (EELV) class orbital launch vehicles.
  - As an example of SLS capability, a bi-propellant propulsive ESPA Grande class Spacecraft could be launched with five FANTM Payload Carriers
    - Total Payload Support Mass (per Port): ~450 kg
    - Payload Mass (per port): Up to 300 kg (multiple CubeSats)
    - Internal Dimensions: .61 x .61 x .81 m

SLS ESPA-type Payload Destinations Beyond Earth Orbit



Destination	Venus Orbit	ES-L1	Lunar Polar Orbit	Flyby of Martian Moons	Asteroid Belt Flyby
Assumed Post-TLI Delta-V (m/s)	2,324	600	570	600	1,863
Max Payload Capacity (kg)	Up to 2,250				

Questions?

- **SLS Mission Planner's Guide Available**

https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170005323.pdf

- **SLS Payload Survey Opportunity** (in MPG)
- **Contacts:**

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david.a.smith-3@nasa.gov
Dr. Paul Bookout, Secondary P/L
paul.bookout@nasa.gov

S³VI Strategy

https://www.nasa.gov/smallsat-institute

Jointly Sponsored by the Space Technology Mission Directorate and the Science Mission Directorate

Backup charts …

Tracking Mission Opportunities:

(http://soma.larc.nasa.gov/standardao/pdf_files/SMDSolicitationPlanningList.pdf)

NASA Science Opportunity	Planned AO Release Date	AO Required Launch Window
Heliophysics STP-5 AO & MOO	NET Q3 FY 2017	AO + ~6.5 years
Heliophysics MIDEX AO/MOO	NET Q1 FY 2018	AO + ~6.5 years
EVI-5 AO (every 18 months)	NET Q2 FY 2018	AO + ~6.5 years
LWS (GDC) AO & MOO	Q4 FY 2018	AO + ~6.5 years
Astrophysics Explorers MOO	NET Q4 FY 2018	AO + ~6.5 years
Astrophysics SMEX	NET Q2 FY 2019	AO + ~6.5 years
EVM-3 AO	TBD	AO + ~6.5 years

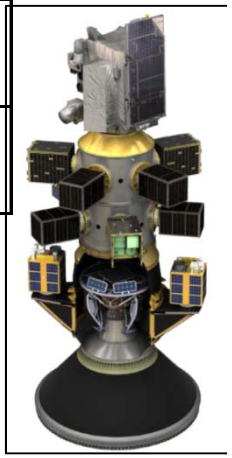


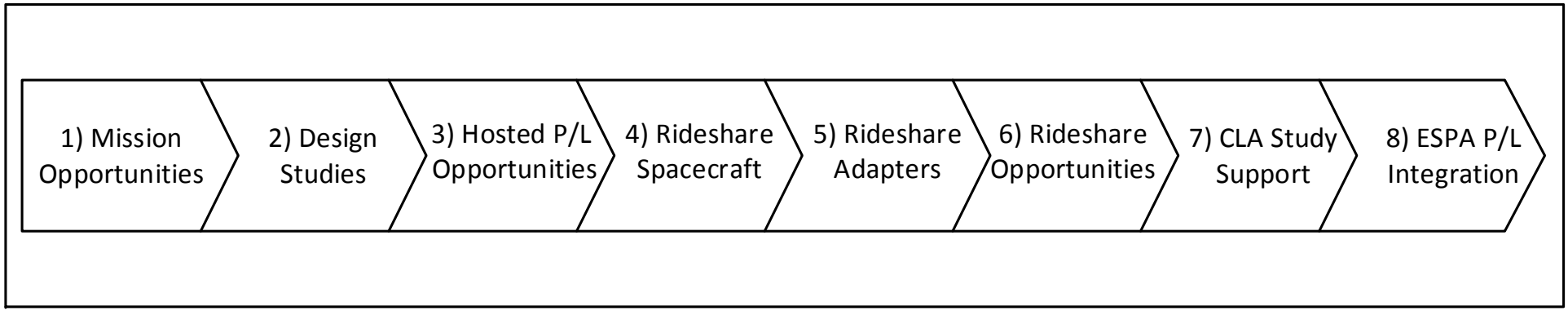
photo credit ORBCOMM, SpaceX, SNC

Small Payload Rideshare Association (SPRSA)

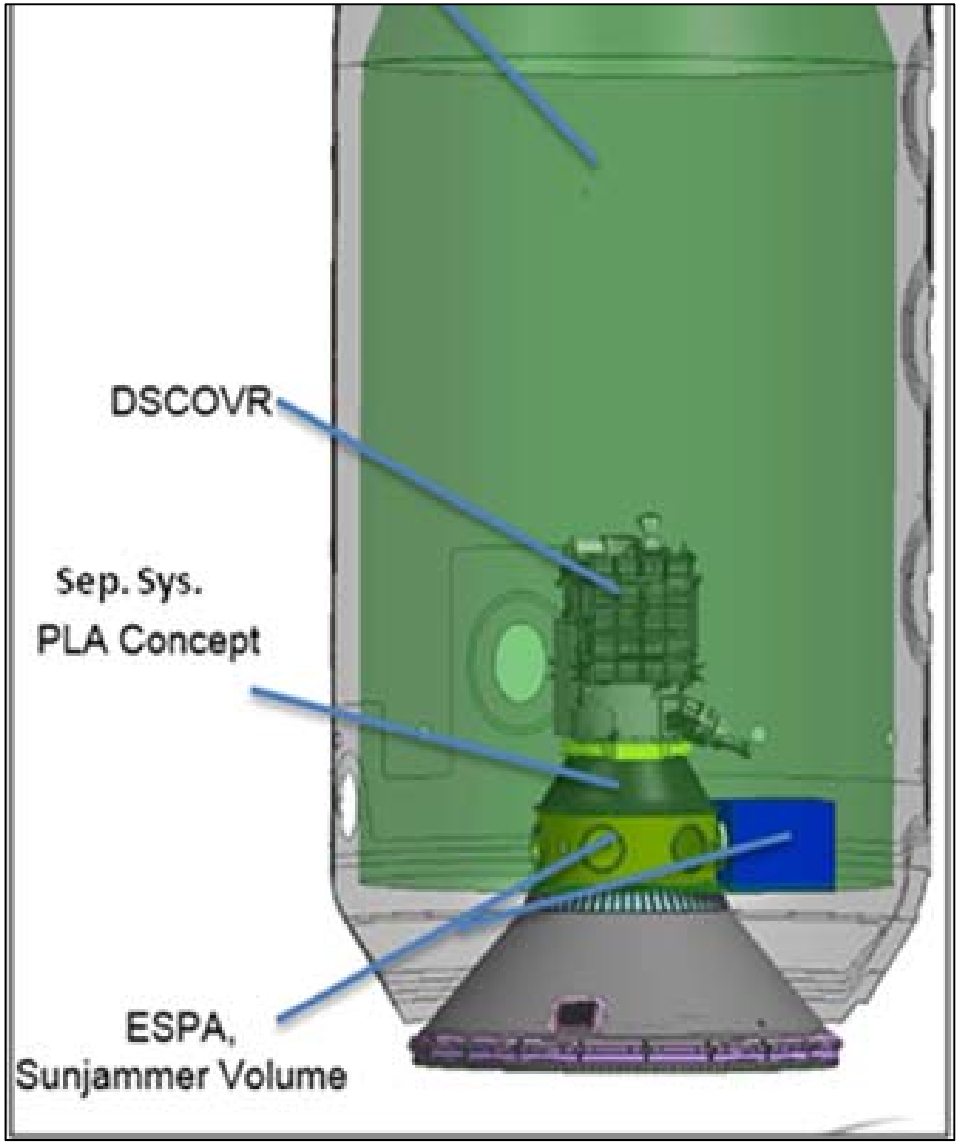
Access to Space Technical Committee

https://www.sprsa.org/

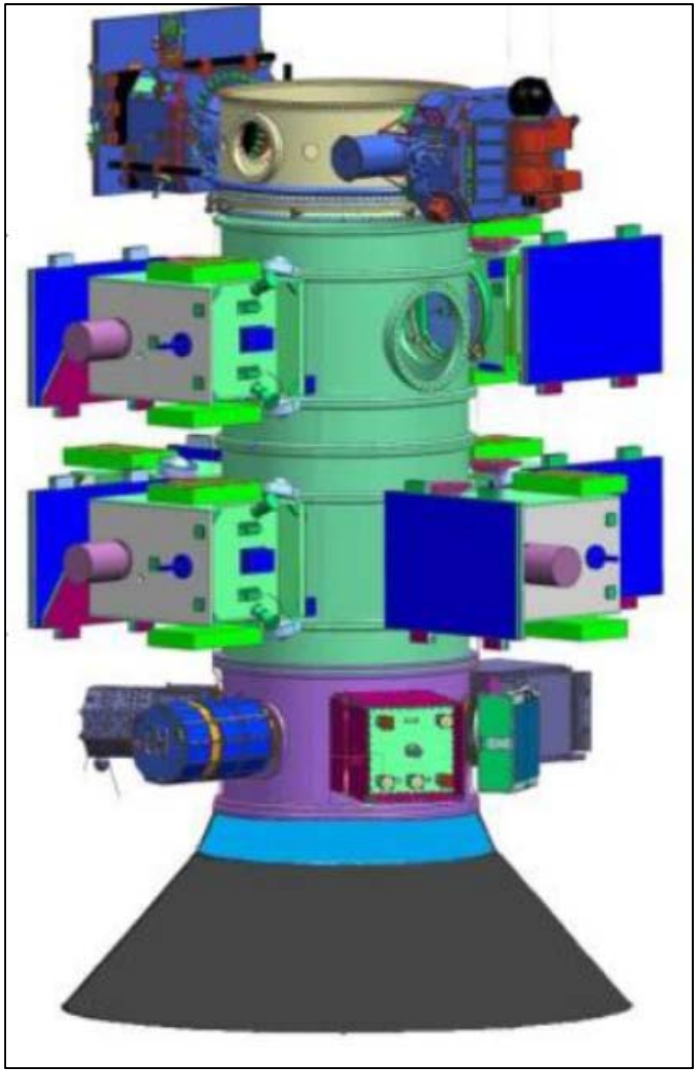
This committee will address the options and opportunities for access to space. The focus will be on the value chain of getting to space. This committee tracks the state of the access to space value chain and reports on their findings.



Rideshare: Enabling Future Missions

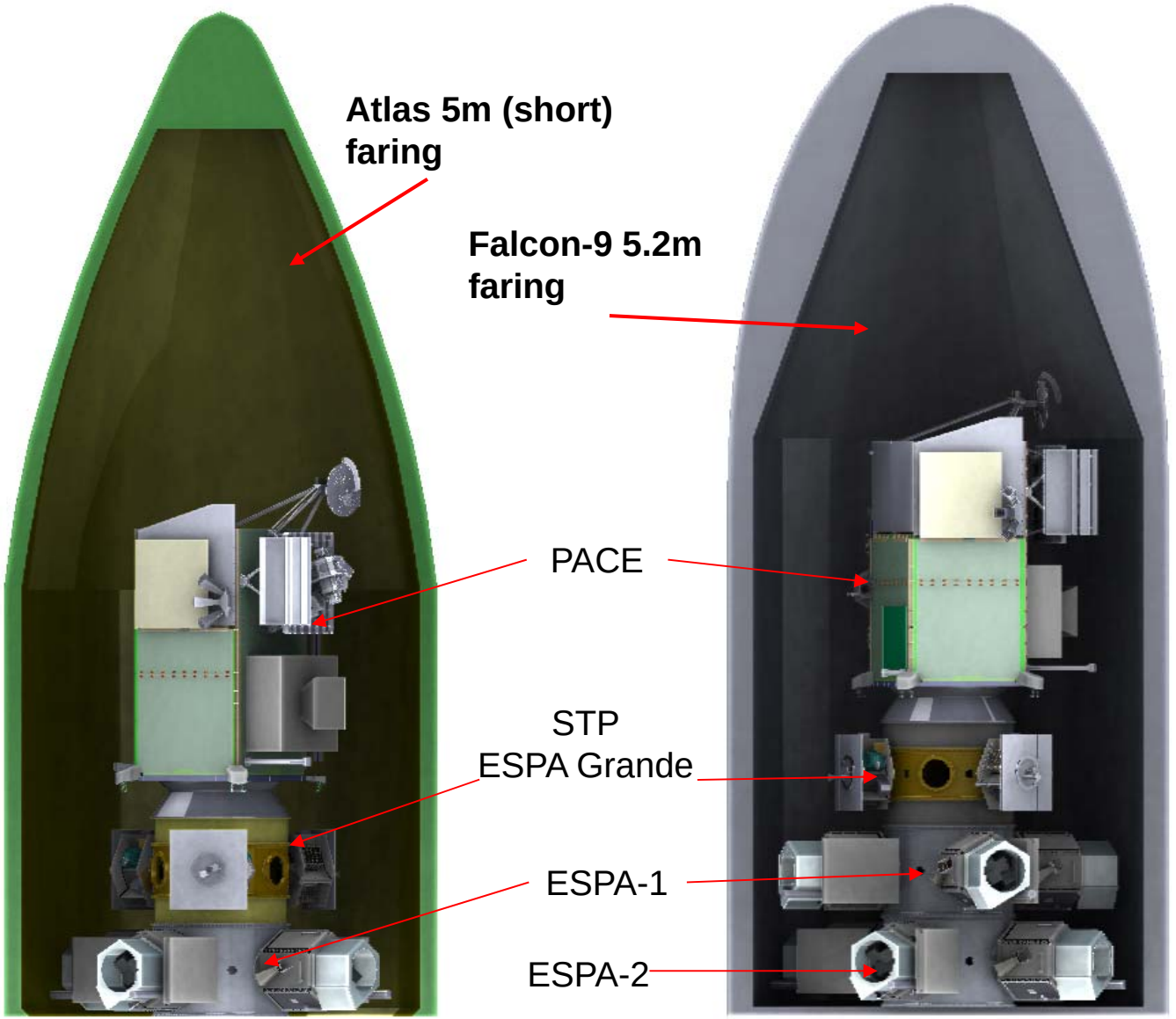


Past Missions (DSCOVR)



Future Multi-missions (STP-2)

PACE/Air Force Collaboration: A Possible Example of Joint Agency Collaboration



NASA Primary Missions w/Rideshare

Candidate Primary Mission	Launch Date	Orbit	Apogee (km)	Perigee (km)	Inclination (deg)	Rideshare Adapter	Decision Date
Sentinel-6 (JPL)	2020	Polar, Cir.	1336km	1336km	66 deg	ESPA Option	9/15/2017
Landsat-9	12/2020	Polar	700km	700km	98.2°	ESPA Option	8/15/2017
SWOT (JPL)	4/2021	Polar, Cir.	857km	857km	77.6 deg	ESPA Grande	7/30/2017
JPSS-2	7/2021	Polar, Cir.	810km	810km	98.5 deg	ESPA Grande	1/2/2018
JPSS-3	1/2024	Polar, Cir.	810km	810km	98.5 deg	ESPA Grande	TBD

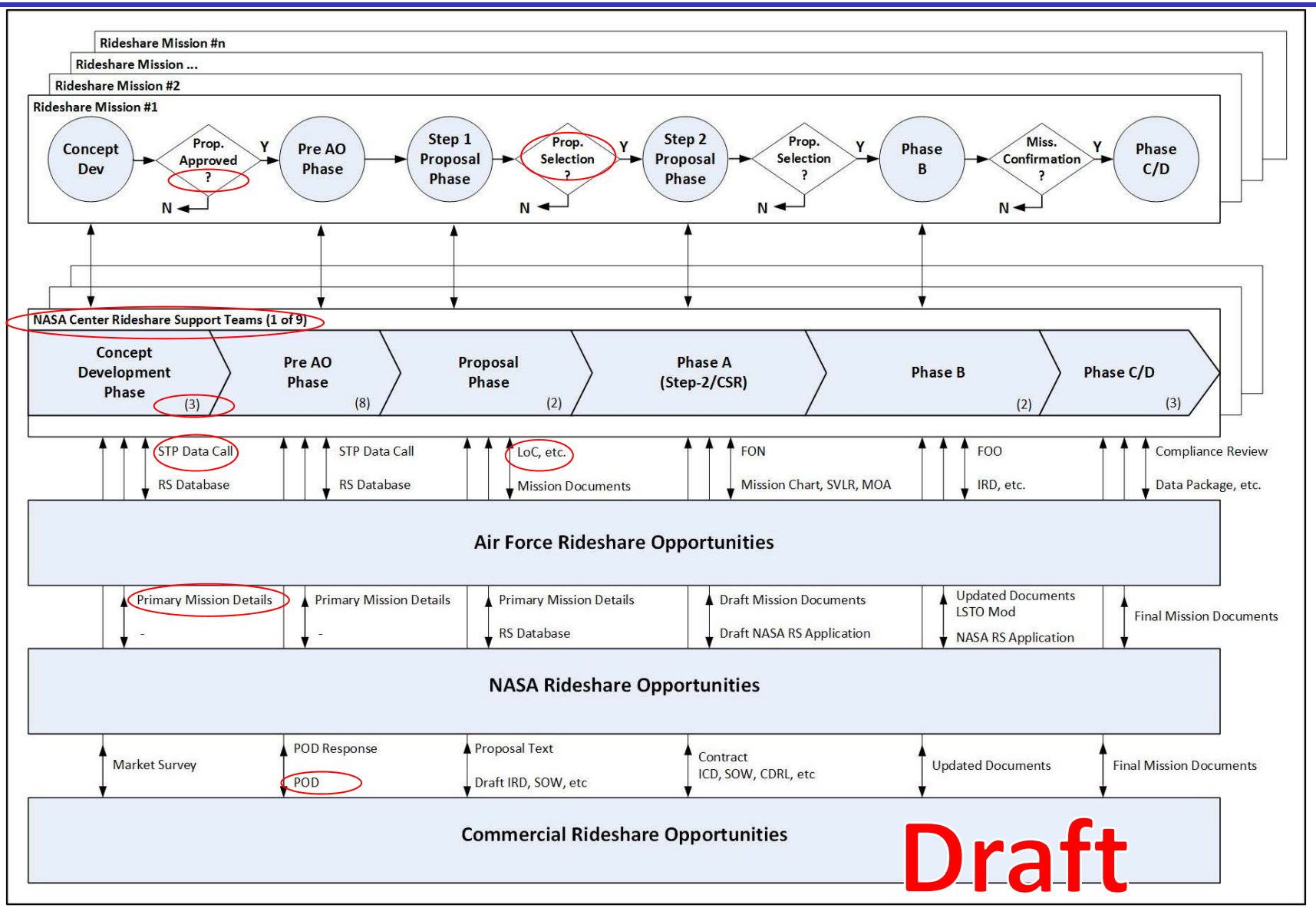
Potential SLS Propulsive Payload Ring Missions

SMD Planetary Science Deep Space Small Spacecraft Study Missions

CAESAR	Several 6U CubeSats will perform a low velocity flyby of a Near Earth Asteroid and transmit data back to Earth
Aeolus	24 U CubeSat to remain in Mars orbit for two years to obtain Mars thermal and wind environment data
PRISM	12U CubeSat will study the composition of Phobos, one of Mars Moons
CUVE	CubeSat UV mission to study Venus' atmospheric chemistry and dynamics
Lunar WATER	Study water, in its various forms, on the Moon
Mars Missions	Several potential Mars missions have been identified

Draft NASA/Goddard Rideshare Process

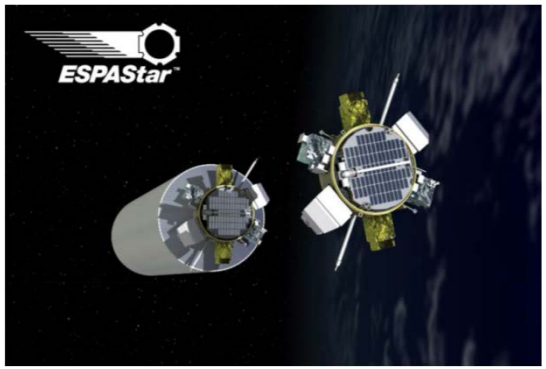
(NASA Center Rideshare Support: GSFC, ARC, GRC, JPL, LaRC, MSFC, KSC, & WFF)



NASA & Air Force/STP Collaborations
(Rideshare Missions)

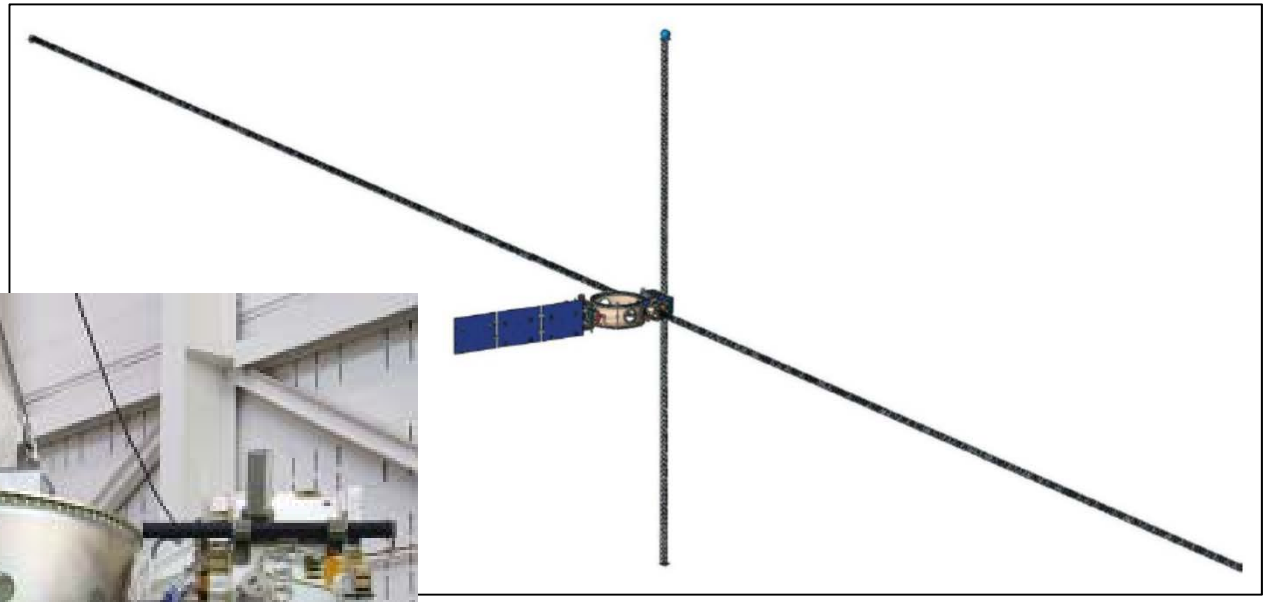
Mission	NASA Org.	Mission / Launch Date	URL / Reference
CINDI/TWINS, HP	GSFC/Explorers	Apr-08	https://explorers.gsfc.nasa.gov/unex_mo_intern.html
GeneSat (CubeSat) ORS, Minotaur-I	Ames	Dec-2006	https://www.nasa.gov/centers/ames/missions/2007/genesat1.html
PharmaSat (CubeSat) ORS, Minotaur-I	Ames	Nov-2009	https://www.nasa.gov/mission_pages/smallsats/pharmasat/main/index.html
O/OREOS (CubeSat) STPSat-2/Minotaur-IV	Ames	Nov-10	https://www.nasa.gov/centers/ames/news/releases/2010/10-109AR.html
FastSat, ESPA S/C STPSat-2/Minotaur-IV	Marshal	Nov-10	https://www.nasa.gov/mission_pages/smallsats/fastsat/ (NASA Payloads)
TCTE, HP on ESPA S/C STPSat-3/Minotaur-I	NOAA/Goddard	Nov-2013	https://www.nasa.gov/content/goddard/building-tcte-the-perfect-combination-of-enthusiasm-spare-parts-and-resources/
DSCOVR Spacecraft Dedicated Falcon-9	NOAA/Goddard	Feb-2015	https://www.nesdis.noaa.gov/content/dscovr-deep-space-climate-observatory
OTB-1 ESPA S/C STP-2/Falcon Heavy	STMD/TDM/MSFC	Q4, 2017	https://www.nasa.gov/sites/default/files/atoms/files/kortes_tdm_tagged.pdf
GPIM ESPA S/C STP-2/Falcon Heavy	STMD/TDM/MSFC	Q4, 2017	www.nasa.gov/mission_pages/tdm/green/
LCRD Hosted P/L STPsat-6 / TBD	STMD/TDM/MSFC	2019	https://www.nasa.gov/mission_pages/tdm/lcrd/index.html
TEMPO HP on Com S/C	SMD/ESSP/LaRC	2021	https://fpd.larc.nasa.gov/tempo.html
SOCON (CubeSat)	GSFC/Code 610	2019	Project in Phase C/D
MiniCarb (CubeSat)	GSFC/Code 610	2019	Project in Phase C/D
RadSat (CubeSat)	GSFC/Code 450	2021	Project in Phase B
STP-H3, MLI Aerogel STP-H4, Earth imagery STP-H3, Lightning Imag.	NASA/JSC/AFRL NASA/JSC/GSFC NASA/JSC/MSFC	Mar-2011 Mar-2013 Mar-2016	Space Station Missions: H3: MLI using Aerogel as thermal isolator; H4: Earth imagery & terrestrial gamma ray flashes (SpaceCube) ; and H5: Lightning Imaging Sensor (LIS)

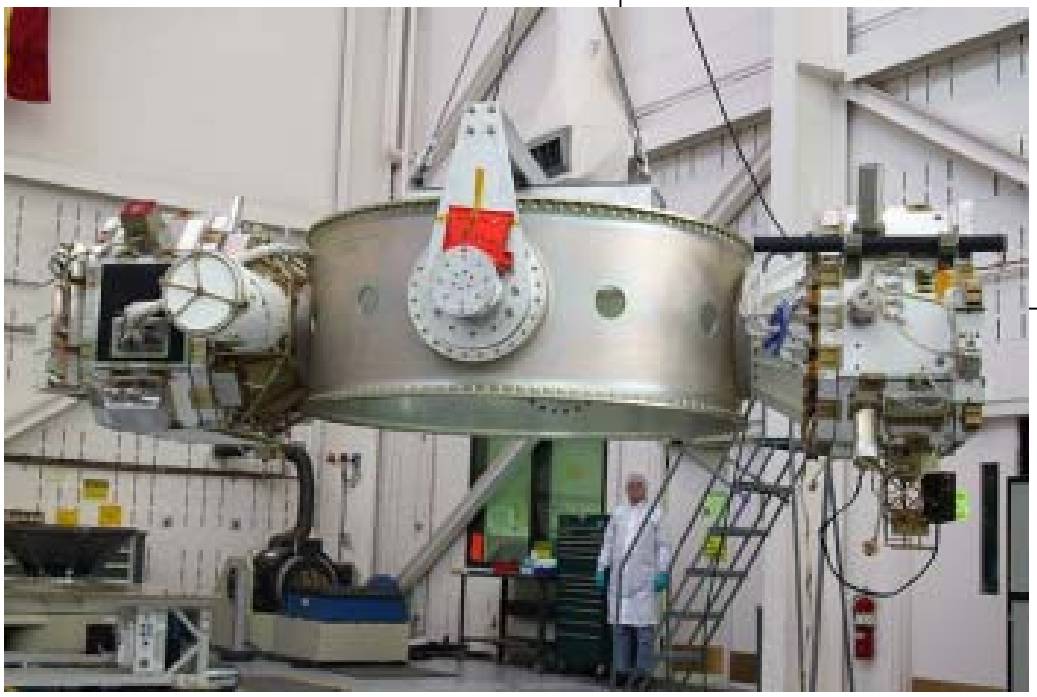
Rideshare Example: The ESPAStar Propulsive ESPA



Attribute	ESPAStar
Payload Capacity	6 fixed or up to 12 separable
Payload Mass	1086 kg (181 kg per port)
Mission Duration	5 Years
Downlink	1.6 Mbps, AFSCN-compatible, Type 1 encryption
Attitude Knowledge	< 10 µrad, 1 Sigma
Positional Knowledge	<10 m w/GPS
Jitter	<10 µrad, 1 Sigma, <0.1Hz
Delta V	400 – 800 m/sec (1086-175 kg P/L mass)
Electrical Interfaces	Power, Data, Discrete IO
Power Available to Payloads	950 W
Flight Regimes	LEO, GTO, GEO

Rideshare Example: DSX, A Propulsive ESPA





DSX Program: SNC provided the bus and payload modules for AFRL's DSX mission, which characterizes the medium-Earth orbit environment using unique science instrumentation and large deployables from an ESPA primary structure.

Rideshare Example: SpaceFlight SSO-A

(575km SSO, 10:30 and 575km x 40,000lm; 3 burns; LRD: Q4 2017)

Launch Vehicle

SpaceX Falcon9

Vandenberg AFB, CA

Integrated Payload Stack

- Large rideshare microsatellite at top position
- Two SHERPA rings
- One Multipayload Adapter System (MAS), SpaceIL inside

CONOPS

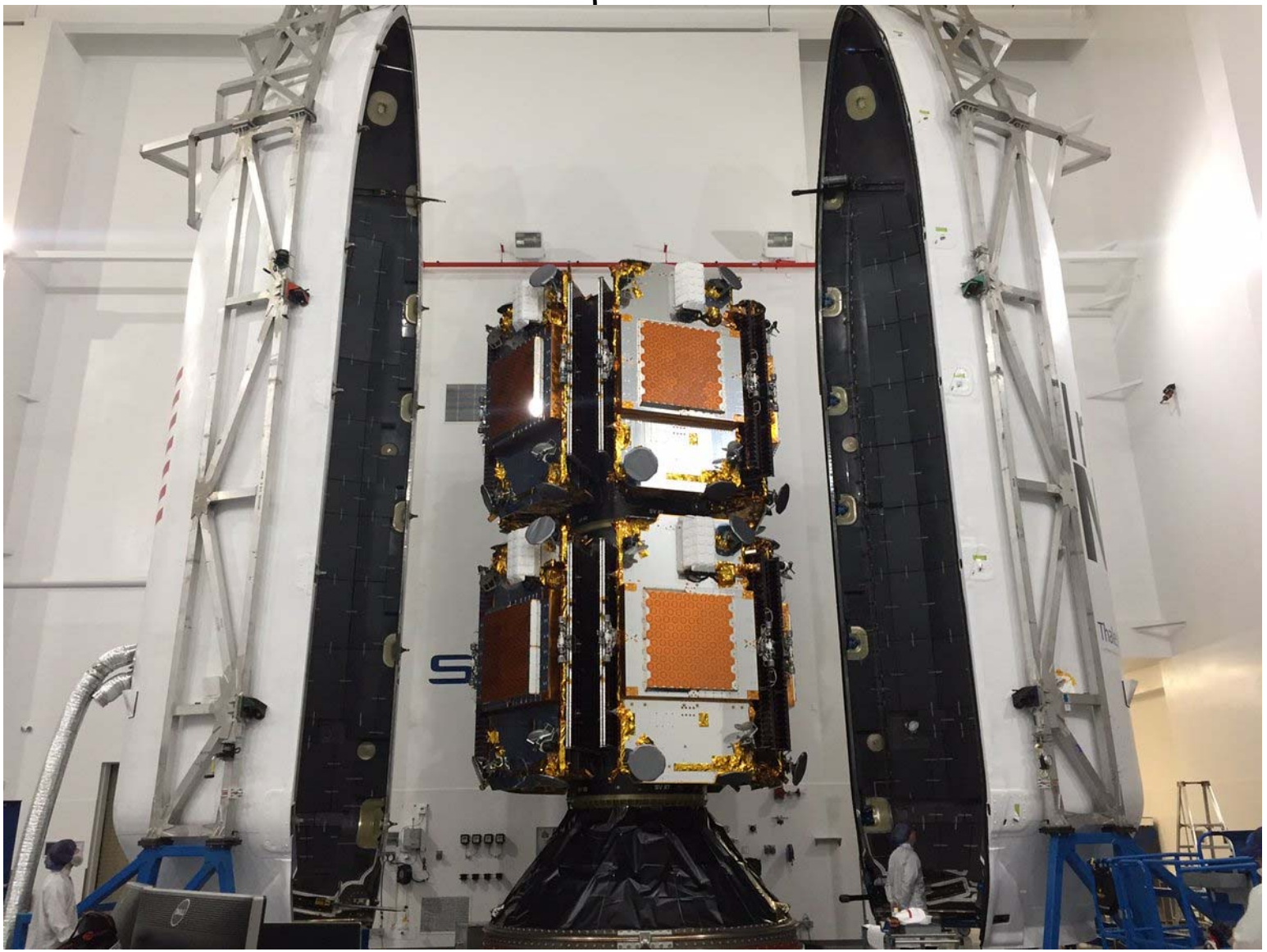
At initial orbit, top position payload separates, SHERPA rings separate, SHERPA payloads then independently deploy via SHERPA sequencer

Falcon 9 relights, goes to a 575 x 40,000km orbit

SpaceIL propels itself to make a lunar intercept

Rideshare Example: 10 Iridium satellites on a F9

(each tier of the two-part dispenser holds five satellites)



Rideshare Example: ORBCOM OG2-1 & OG2-2

July 2014 and December 2015
Seventeen OG2 satellites launched on two Falcon 9 missions

ESPA rings at Moog CSA in Mountain View

photo credit ORBCOMM

Moog engineers assembling ESPA stack

SoftRide installed at SpaceX SLC-40

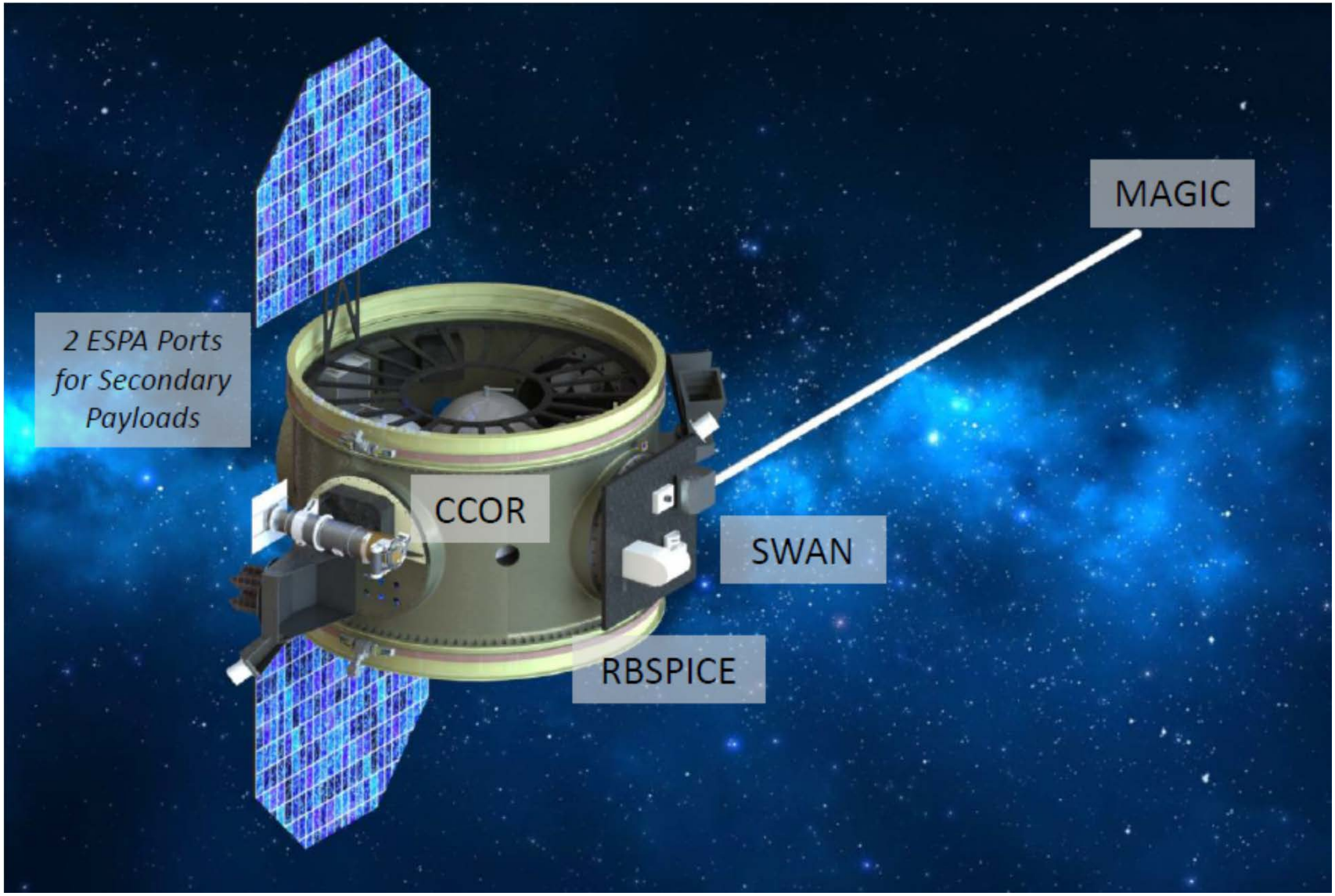
Photo Courtesy of Sierra Nevada Corporation

SpaceX SLC-40 at Cape Canaveral

OG2 satellite deployment on orbit

Falcon 9 launch and landing 21 December 2015

Rideshare Example: ELLIE Mission Concept to L1



ELLIE: NASA/Ames, NASA/Langley, and Moog Mission Concept

MDL – Services and Capabilities

Services:

- End-to-end mission concept development
- Engineering evaluations
- Trade studies
- Technology, risk, and independent assessments
- Requirement refinement and science traceability
- Mass, power, data resource allocation
- Master Equipment Lists for cost modeling

Full Range of Capabilities:

- Standard and low thrust trajectory design to LEO, GEO, libration, lunar, and deep space locations
- Observatory design of single spacecraft, constellations, formation flying, and distributed systems
- Ground system concept development, including services and products
- Launch vehicle accommodations
- End-of-Mission considerations including controlled and uncontrolled de-orbit, reconnaissance and landing, sample return, etc.

Rideshare P/L Integration Process

Rideshare Activity/Milestone	Date	Comment
Early Mission Assessment	L-48 Months	Based on STP RUG requirements
Approval of APL inclusion	L-27 Months	Based on STP RUG requirements
Compatibility Review	L-27 Months	Based on STP RUG requirements
Rideshare P/Ls LV Requirements	L-27 Months	Based on STP RUG requirements
Rideshare P/Ls drawings, schematics, & models	L-36 Months L-12 Months	Initial delivery date Final delivery date
P/L Parts List & Materials List for Environmental Assessment & Contamination Control	L-36 Months L-12 Months	Initial delivery date Final delivery date
Rideshare P/Ls Baseline Review	L-25 Months	Based on STP RUG requirements
Compliance/Mission-Peculiar Design Review	L-6 Months	Initial rev. L-18 Months
Rideshare P/Ls delivered to Wallops / ESPA I&T	L-4 Months	Based on STP RUG requirements
ESPA w/ P/Ls delivered to CCAFS / LV-ESPA I&T	L-2 Months	
Launch Date	L	

ESPA Heritage

Mission	L/V	Carrier	Launch Date	No. of S/C
STP-1	Atlas V	ESPA	March 2007	6
LCROSS*	Atlas V	Propulsive ESPA	June 2009	N/A
OG2 Mission 1	Falcon 9	ESPA Grande (2)	July 2014	6
AFSPC-4	Delta IV	ESPA	July 2014	1
OG2 Mission 2	Falcon 9	ESPA Grande (3)	December 2015	11
AFSPC-6	Delta IV	ESPA	August 2016	0**
SHERPA / Spaceflight	Falcon 9	ESPA Grande	Late 2016	> 80
SHERPA / Spaceflight	Falcon 9	ESPA	Late 2017	6 ports
STP-2 (DSX Mission)* / AFRL	Falcon 9 Heavy	ESPA	2017	N/A
EAGLE / AFRL	Atlas V	Propulsive ESPA	NET 2017	2 S/C + 4 Payloads
Developed Mission Concepts (Publically Available Information)				
OMS/Millennium Space	--	Propulsive ESPA	Developed Concept Has not flown yet	Up to 4
MULE/Busek	--	Propulsive ESPA – Electric Propulsion	Developed Concept Has not flown yet	Up to 6
OMEGA / Moog-Surrey	--	Propulsive ESPA Grande	JPL TeamX in 2012	6
ELLIE/Moog (OMV to L1)	--	Propulsive ESPA Grande	Proposal Submitted	4 ports

Note: Information provided by Moog Inc

*LCROSS and DSX used the ESPA as the spacecraft bus structure and did not deploy payloads
**Did not carry any payloads

Some Commercial Rideshare Opportunities

(SPRSA: Secondary Adapters Technical Committee)

- **Rideshare third-party brokers/integrators**
  - **Adaptive Launch Solutions (ALS) (1)**
  - **bSpace (1)**
  - **NanoRacks LLC (1)**
  - **Spaceflight Industries (1)**
  - **TriSept Corporation (1)**
  - **Tyvak Nanosatellite Systems Inc. (1)**
  - **Moog Inc. (1)**
  - **Surrey Satellite Technology (1)**
- **Large US L/V w/secondary capabilities**
  - **Antares (including Cygnus) [Orbital] (1)**
  - **Atlas V [United Launch Alliance (ULA)/Lockheed Martin Com. Launch Ser] (1)**
  - **Delta IV [ULA/Boeing Launch Services] (1)**
  - Falcon 9 (including Dragon) [SpaceX]
  - Falcon Heavy [SpaceX]
  - Space Launch System [NASA]
- **US small launchers**
  - ~~ALASA [DARPA/Boeing]~~
  - ~~Alpha [Firefly] (2)~~
  - Athena II [Lockheed Martin]
  - **Electron [RocketLab] (2)**
  - Nano-sat/Micro-sat Launch Vehicle (Vector-1) [*Vector Space Systems*]
  - GO Launcher 1, 2 [Generation Orbit]
  - **LauncherOne [Virgin Galactic] (2)**
  - Minotaur I, IV, V, VI, C [Orbital ATK]
  - Neptune [Interorbital]
  - **Pegasus [Orbital ATK] (1)**
  - Stratolaunch [Vulcan Aerospace]
  - ~~SuperStrypi [Sandia National Labs]~~
  - Terrestrial Return Vehicle (retrieval from ISS only) [Intuitive Machines]
  - Ventions Nanolauncher [Ventions]

(1) More information available on each vendor (quad charts & launch schedules)

(2) Venture Class Launch Services

SPACEFLIGHT

One Stop Integration & Launch Services

- Spaceflight is a next-generation, integrated space services and solutions company that is changing how small satellites are built, launched and operated to improve access to space and enable persistent global awareness
- Business Sectors
  - Launch & Integration Services
  - Data Analytics / Platform
  - Small Space Systems Development
  - Networks

- Small Business with ~ 145 employees
- Established in 1999 under Andrews Space
- Providing Launch Services since 2010
  - 115 payloads launched to date; 170+ to come
- 5-Year: GSA Contract: GS-00F-036DA
- Other commercial and USG contracts

Valeries@spaceflightindustries.com Director Govt Business

Scotts@spaceflightindustries.com Chief Engineer Mission Development & Design

www.spaceflight.com

Products/Services:

- On-line pricing & payment schedules for standard missions
- Rideshare & Dedicated Rideshare Missions to SSO and GTO and other orbits
- Experienced staff & in-house integration facility to provide
  - Documentation, ICDs, MA, MSPSP, Master schedule, shipping, fit-check
  - SHERPA, Adapters, Separation Systems

SPACEFLIGHT

Rideshare Pricing

- Spaceflight commercial pricing based on payload size and mass
- Government Pricing/Contracting
  - Subcontractor on NASA Ames Contract supporting Civil and DoD programs
  - GSA Schedule and pricing available

	Containerized			Satellite Class							
Payload Type	3U	6U	12U	50 kg	100 kg	150 kg	200 kg	300 kg	450 kg*	750 kg*	1000 kg*
Length (cm)	34.05	34.05	34.05	80	100	100	100	125	200	300	350
Height/Dia (cm)	10.00	10.00	22.63	40	50	60	80	100	150	200	200
Width (cm)	10.00	22.63	22.63	40	50	60	80	100			
Mass (kg)	5	10	20	50	100	150	200	300	450	750	1000
Price – LEO	$295	$545	$995	$1,750	$3,950	$4,950	$5,950	$7,950	$17,500	$22,000	$28,000
Price – GTO	$650	$995	$1,950	$3,250	$5,950	$6,950	$7,950	$9,950	CALL	CALL	CALL
Price - GSO/LLO	$995	$1,990	$3,250	$6,500	$9,950	$12,950	$15,950	$19,900	CALL	CALL	CALL

* Assume vertical integration with the Launch Vehicle where nominal diameter and length is given

*** Priced in thousands. Specific mission pricing may vary

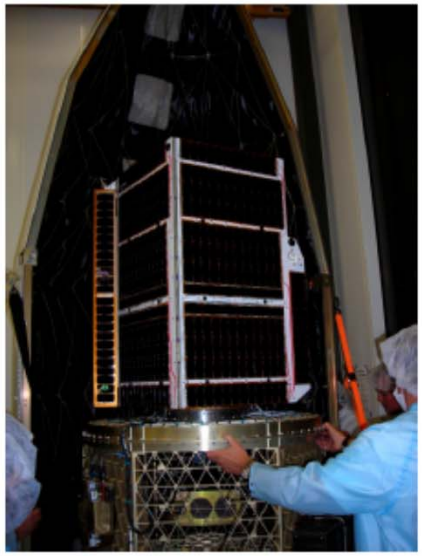
SPACEFLIGHT

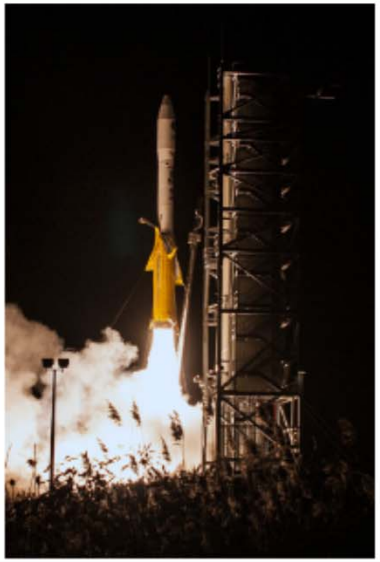
Upcoming Rideshare and Dedicated Launches / Missions

Spaceflight Proprietary - US Govt Only: Several Missions in Design					
Vehicle	**Name**	**Window**	**Year**	**Incination**	**Altitude**
Falcon 9	SSO-A	Q1/2	2018	SSO	575
Electron	RLNZ	Q2	2018	45	450
ISS/Antares	OA-9	Q1/2	2018	52.6	450-500
ISS/Falcon 9	SpX-15	Q2/3	2018	52.6	450-500
Electron	RLNZ	Q3/4	2018	45	450
Falcon 9	GTO-1	Q4	2018	GTO	185x60,000
ISS/Falcon 9	SpX-16	Q4	2018	52.6	450-500
ISS/Antares	OA-10	Q4	2018	52.6	450-500
Electron	RLNZ	Q4	2018	SSO	400-500
ISS/Falcon 9	SpX-17	Q4	2018	52.6	450-500
Electron	RLNZ	Q4/1	2018/2019	SSO	450
ISS/Antares	OA-11	Q4/1	2018/2019	52.6	450-500
ISS/Falcon 9	SpX-18	Q4/1	2018/2019	52.6	450-500
Falcon 9	SSO-B	Q4/1	2018/2019	SSO	500-525
ISS/Falcon 9	SpX-19	Q2/Q3	2019	52.6	450-500
ISS/Falcon 9	SpX-20	Q4	2019	52.6	450-500
Electron	RLNZ	H2	2019	SSO	450-500
Falcon 9	GTO-TBD	Q4	2019	27	35,786
Antares	OA-TBD	Q2/3	2019	52.6	450-500
TBD	GTO-TBD	Q4/1	2019/2020	27	35,786
Falcon 9	SSO-C	H2	2020	SSO	500-700

Finalizing agreements with all new entrants and have additional capacity for specialized missions. Please inquire if you have questions.

TriSept Corporation





- *Certified Small Business (Founded 1994)*
- *Average Employee Experience: 31+ Year*
- *100+ spacecraft launched on 20 different LV's from 10 different ranges/sites*
- *Small Satellite Integration Pioneers*
- *Launch / Rideshare brokering*
- *Leading multi-payload mission integrators*

Jason R. Armstrong
Director Small Satellite Solutions
15036 Conference Center Dr., Suite 550
Chantilly, VA 20151
703-297-4622 www.trisept.com
GSA schedule (GS-10F-0118V)
NAICS Codes: 541330, 54130, 541511, 541690, 541712, 541519, 336419

- *Rideshare opportunities for spacecraft from 1U to 1,000's of Kg's*
- *Dedicated small launch mission's*
- *Dedicated Rideshare mission's*
- *Commercial and Government launch services*
- *Integration support for existing mission's*

TriSept : Rideshare Opportunities

TriSept Small Satellite Solutions

Mission	Targeted Launch	Orbit	Status/Comments
TriSept Dedicated Rideshare	1st Qtr 2018	450 km circular, 30° Inclination	Up to 100kgs
Rideshare opportunity	Mid 2018	500 km circular, SSO, LTAN 10:30 or 1:30	Multiple options up to 200kgs and many CubeSat slots (12U, 6U and 3U)
Rideshare opportunity	Late 2018	MEO	Multiple options for SmallSats
TriSept Dedicated Rideshare	1st Qtr 2019	500km, SSO	Up to 1000kgs
Rideshare opportunity	Mid 2019	TBD	Many options still available

Tyvak Nano-Satellite Systems Inc.

3U P-POD

3U NLV Rail-POD

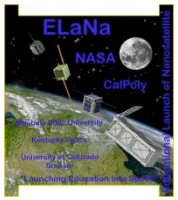
6U NLAS

12U NLAS

ULA ABC ~100kg

ESPA Class

Supporting USG SmallSat Enablers

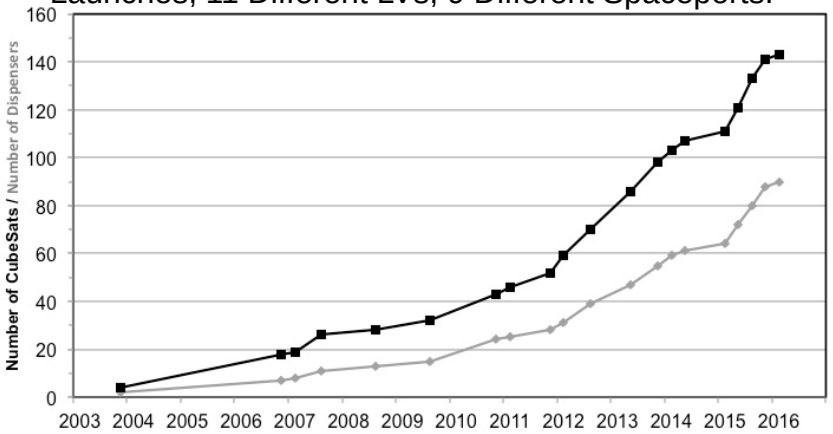


NASA ELaNa and CSLI

DoD, USAF, NRO

Flight Heritage with Cal Poly:

- Completed To Date: 143 SmallSats launched, 21 Launches, 11 Different LVs, 9 Different Spaceports.



Company Information:

- ***VP, Launch Services***
  Roland Coelho
  roland@tyvak.com
  805-704-9756

  Mission Manager
  Justin Carnahan
  justin.carnahan@tyvak.com
  805-405-8890
- 15265 Alton Parkway Suite 200, Irvine CA, 92618
- Tyvak provides turnkey nanosatellite and microsatellite vehicles, launch services and solutions to government and commercial customers at a fraction of the cost of traditional spacecraft service providers .
- Formed in 2011, 50+ engineers, offices in US and Italy
- NASA, DoD, Commercial, International contracts completed and in process. Personnel completed 21 launch campaigns to date and 10+ launch campaigns on contract in 2016-18.

Tyvak SmallSat Launch Process:

Tyvak Responsible For

- Requirements and Interface Definition
- Separation System & SmallSat Mission Support
- Hardware Certification
- SmallSat Integration
- Acceptance Test/CoFR
- Delivery to LV
- Assistance with LV Integration

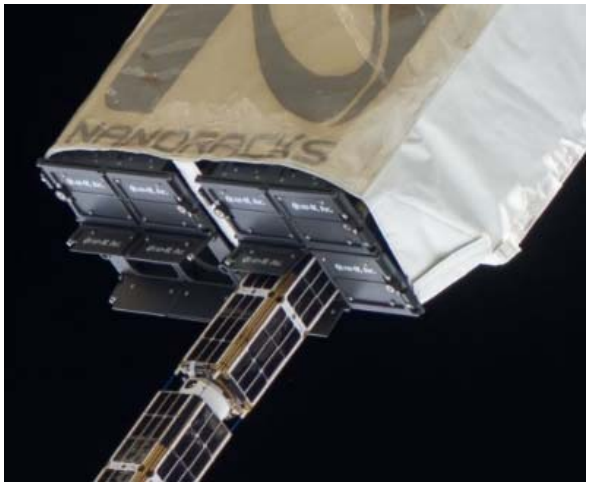
Launch Vehicle Focuses On

- Launch
- Payloads to Orbit

Tyvak Rideshare Opportunities

Year	LEO (~500x~500)	Polar (Apo x Per)	MEO (1100x185)	GEO (35786x35786)	Other
2017	4Q_500km_50deg	1Q_600km_SSO 2Q_500km_SSO 3Q_600km_SSO 4Q_500km_SSO			4Q_GTO
2018	3Q_500km_~40 deg	2Q_500km_SSO 4Q_500km_SSO		2Q_SuperSynch	1Q_GTO 3Q_GTO
2019	Continued Availability to LEO	Continued Availability to SSO		Continued Availability to Sub/Super_Synch	1Q_GTO 3Q_GTO 3Q_Escape
2020	Continued Availability to LEO	Continued Availability to SSO		Continued Availability to Sub/Super_Synch	Continued Availability to GTO
2021	Continued Availability to LEO	Continued Availability to SSO		Continued Availability to Sub/Super_Synch	Continued Availability to GTO
2022	Continued Availability to LEO	Continued Availability to SSO		Continued Availability to Sub/Super_Synch	Continued Availability to GTO
2023	Continued Availability to LEO	Continued Availability to SSO		Continued Availability to Sub/Super_Synch	Continued Availability to GTO

NanoRacks



Heritage / Schedule Information:

- *Commercial ISS Satellite Deployments*
- *External Cygnus CubeSat Deployments*
- *CubeSat Formats*
- *Small Satellite Formats (~100 kg class)*
- *ISS External Platform Hosting*
- *139 CubeSats Deployed to date*
- *Quarterly flights to ISS*

Company Information:

- *Conor Brown, (703) 973-6821, cbrown@nanoracks.com*
- *www.nanoracks.com*
- *Houston, TX, Washington, D.C., San Francisco, CA*
- *40 employees,*
- *established 2009*
- *NASA Services Contract (No Tax ICT)*
- *In partnership with Quad-M*

Product Information:

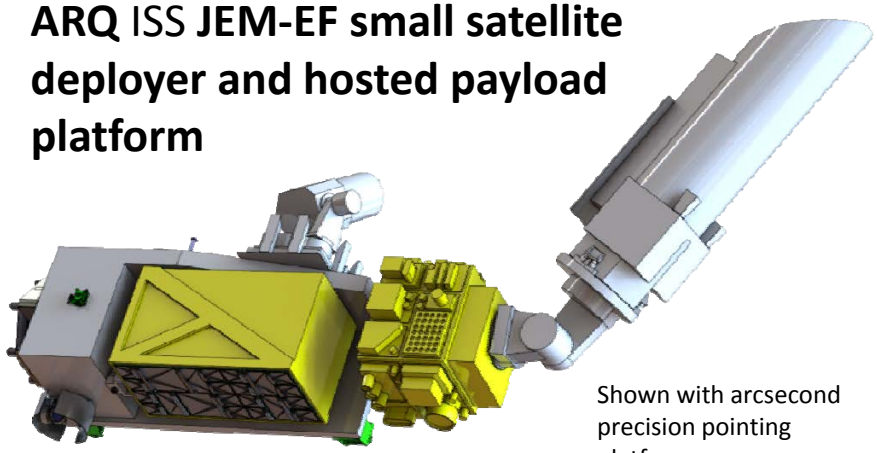
- *NRCSD*
- *Kaber*
- *Cygnus External Deployer*
- *NREP*
- *NR Airlock*
- *Dragon Trunk Deployer*
- *Centaur Aft Bulkhead Deployer*
- *Centaur MegaDeployer*

NanoRacks: Anticipated Launch Opportunities

Year	LEO (~500x~500)	Polar (Apo x Per)	MEO (1100x185)	GEO (35786x35786)	Other
2017	4			1	
2018	4			1	
2019	4			1	
2020	4			1	
2021	4			1	
2022	4			1	
2023	4			1	

bSpace Corp.

ARQ ISS **JEM-EF small satellite deployer and hosted payload platform**



Shown with arcsecond precision pointing platform

Heritage / Schedule Information:

- *Experienced team of space hardware engineers and flight program managers with shuttle, station, & solar system heritage*
- *Now taking satellite & hosted payload customers*
- *First flight spring 2019*

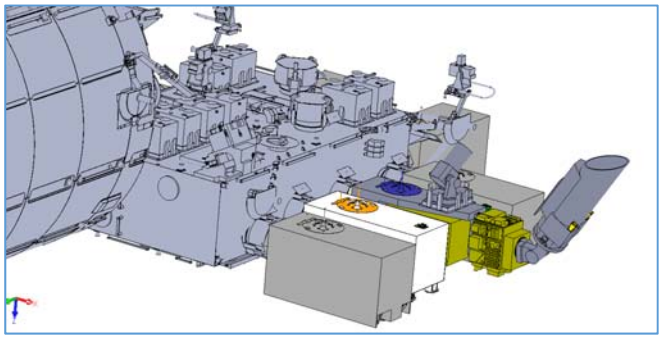
Company Information:

- *POC Jason Budinoff*
- *208-559-7803 cell/txt*
- *jason@bsapcelaunch.com*
- *www.bsapcelaunch.com*
- *500 Yale Ave N, Suite 105, Seattle, WA 98103,*

- *CAGE Code 7PQ45*
- *DUNS 080244843*

Product Information:

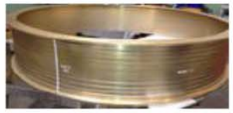
- *Affordable, Predictable, Available service with a minimum of 2 flights per year to ISS*
- *Deploy Satellites from 1U through ESPA including unique sizes and propulsion systems*



ARQ shown on JEM-EF

Adaptive Launch Solutions

Aquila Multi-Manifest Systems



Deck Adapter

Aluminum Deck

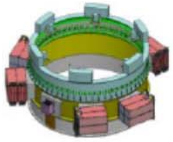
Standard Adapter

Composite Deck

Anisogrid Adapter

Auxiliary Payload Support Unit (APSU)

Integrated Deck & Adapters



Integrated Cubesat Dispensers

Heritage / Schedule Information:

- Aquila meets Atlas V, Delta IV, Antares, Falcon 9 and Minotaur flight and ground environments.

Deck and Adapter Stress Analysis, Dynamic Analysis, Specs & Designs complete. Full Scale Qualification Test (Vibration, Acoustic and Modal Survey) plans, tests and reports complete	 Aquila Full Scale Vibration Test	Reviewed by OSL & ✓
APSU Stress Analysis, Dynamic Analysis, Specs & Designs complete. Qualification Test (Vibration, Shock, Thermal, Thermal Cycle) plans, tests and reports complete. Includes EMI/EMC DET	 APSU Flight Simulation Test	Reviewed by OSL & ✓

Company Information:

- ***Aquila Operations Manager***
  James Parra
  jparra@adaptivelaunch.com
  858-395-2819
- ***Business Development***
  Philip Smith P.E.
  psmith@adaptivelaunch.com
  619-944-2555

- 10620Treena Street, Suite 230, San Diego, California, 92131
- ALS provides pico, nano, micro, mini and small Auxiliary Payloads rideshare mechanical systems, avionics and integration services on Evolved Expendable Launch Vehicle, Medium Launch Vehicles and Small Launch Vehicles.
- SAM reg, DUNS 962127804, CAGE 64BK4, incorporated 2010
- NASA, OSL and Commercial contracts completed and in process. June 2016 backlog over $5M.

Product Information:

- Aquila Multi-Manifest System supports both Multiple Auxiliary Payload and Dual Payload Configurations.
- All components compatible with ESPA, RUAG Separation Systems, Spacecraft Separation Systems and Cubesat Dispensers.
- Aquila Standard Adapter rated at 6,364 kg TRL 9
- Aquila Deck Adapter rated at 6,364 kg TRL 8
- Aquila Deck rated for 1000 kg. TRL 8
- APSU up to 32 individual separation events TRL 8
- APSU integrated battery flown on Missile systems
- ALS Mission Integration Services includes mission integration management, mission integration engineering, launch site engineering, range safety engineering, and launch site integration

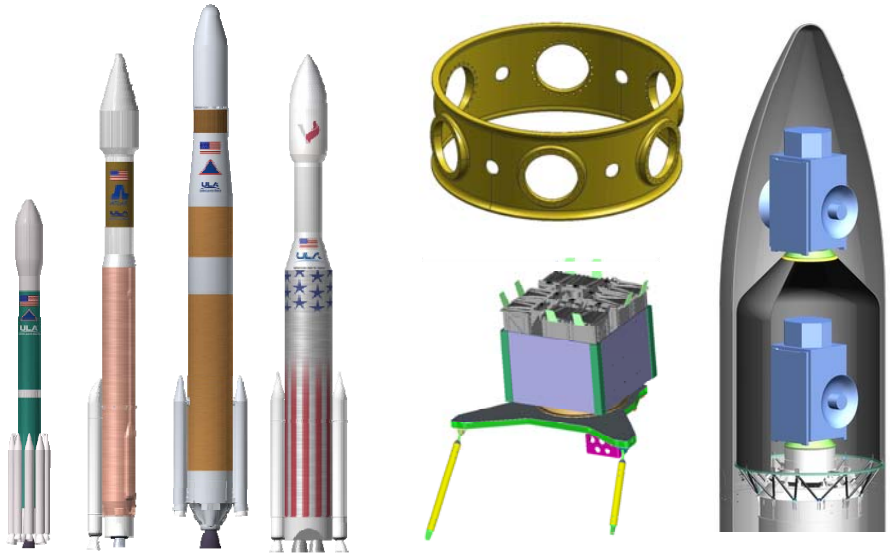
ALS Rideshare Opportunities:

- Mission Opportunity 1
  - Launch Vehicle Atlas V
  - ILC December 2017 or more likely 1st Quarter 2018
  - Primary Customer Commercial
  - Primary Orbit GTO greater than or equal to 185 km by 35,786 km
  - Inclination and orbital position TBD
  - Mass available for rideshare system including Auxiliary Payloads 1000 kg

- Mission Opportunity 2
  - Launch Vehicle Atlas V
  - ILC 3rd Quarter 2018
  - Primary Customer Commercial
  - Primary Orbit GTO greater than or equal to 185 km by 35,786 km
  - Inclination and orbital position TBD
  - Mass available for rideshare system including Auxiliary Payloads 1000 kg

United Launch Alliance

America's Ride to Space



Heritage / Schedule Information:

- *ULA has averaged almost 1 launch per month since Dec 2006*
  - *107 successful launches as of 6/11/2016*
- *9 ULA rideshare launches have delivered 61 small sats to space (including 55 CubeSats)*
  - *An additional 5 rideshare missions currently scheduled*

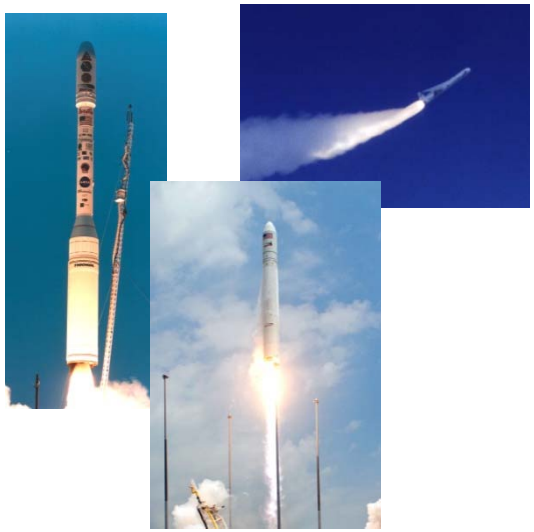
Company Information:

- Mark Schultz, (303) 391-4524, mark.e.schultz@ulalaunch.com
- *http://www.ulalaunch.com*
- *Joint-venture between Boeing and Lockheed Martin; established Dec 2006*
- *3,500 employees across 6 sites*
- *Launch service contracts for USAF, NASA, NRO, and commercial customers*

Product Information:

- *Launch Services*
  - *Atlas V, Delta II, Delta IV, Vulcan Centaur*
  - *Full launch capability to all orbits - GEO, GTO, MEO, LEO, Interplanetary*
- *Rideshare Capabilities*
  - *Aft Bulkhead Carrier, ESPA, AQUILA, Dual Manifest*
  - *Ranges from 1 kg to 5,000+ kg*

Orbital ATK: Commercial Launch Options



Heritage / Schedule Information:

• *Pegasus has 42 launches, with the last 26 completely successful. It has two missions on manifest and has recently announced a partnership with Stratolaunch. Pegasus is available now for launches in 24 months.*

•*Minotaur-C has 9 launches and one on manifest for 2017. It is available now for launches in 24 months.*

•*Antares has 5 launches, with 6 on manifest. It is available now for launches in 24 months.*

Company Information:

•*Warren Frick, 703-948-8192, warren.frick@orbitalatk.com*

• *OrbitalATK.com*

• *Orbital ATK is based out of Dulles, Virginia and has major operating locations in 17 states. It has more than 12,000 employees and was established in 2015 in the merger of Alliant Techsystems and Orbital Sciences Corporation. Orbital ATK's commercial launch vehicles are all available through the NLS-II contract as well as commercially.*

Product Information:

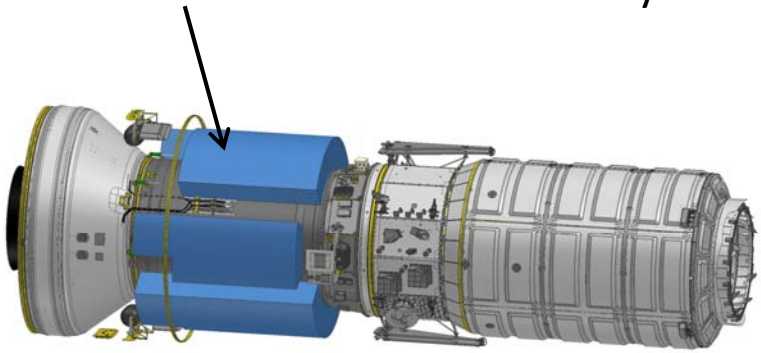
•*Pegasus has a performance up to 1000 lbs, and inclination range of 0 to very highly retrograde due to its mobile, air-launched nature*

•*Minotaur-C has a performance up to 3500 lbs and inclination range of 28.5 degrees to SSO*

•*Antares has a performance range from 1700 lbs to over 16000 lbs and inclination range of 38 to 60+ degrees and SSO.*

Orbital ATK: Antares Secondary P/L

ISS Resupply Mission
Volume Available for Secondary



Heritage / Schedule Information:

- *Orbital ATK Commercial ReSupply Missions launch several times each year. Four flights have successfully been completed and six more planned*
- *Orbit is ~185 x 300 km, Inclined 51.6 Degrees*
- *Current Launch Schedule:*
  - *1Q 2017, 3Q 2017, 4Q 2017*
  - *2Q 2018, 4Q 2018*
- *Orbital ATK has been chosen for CRS-2 contract, with Launch Schedule to be determined*

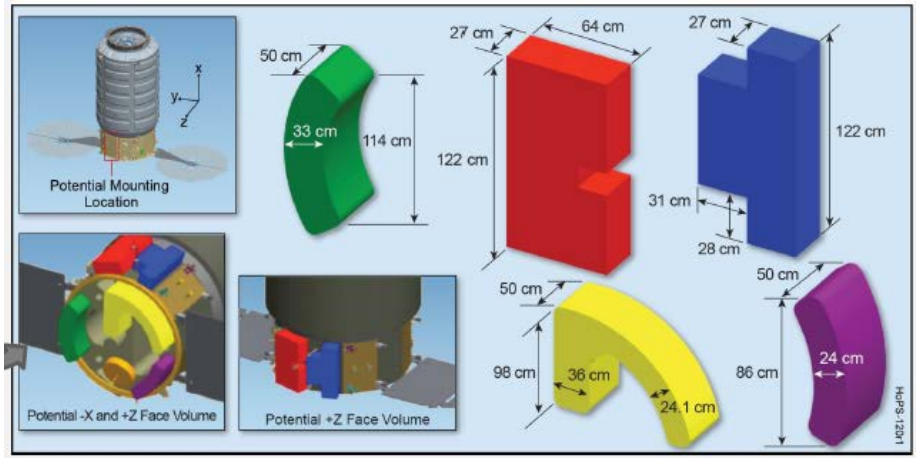
Company Information:

- *Warren Frick, 703-948-8192, warren.frick@orbitalatk.com*
- *OrbitalATK.com*
- *Orbital ATK is based out of Dulles, Virginia and has major operating locations in 17 states. It has more than 12,000 employees and was established in 2015 in the merger of Alliant Techsystems and Orbital Sciences Corporation. Orbital ATK's launch services are available through the NLS-II and OSP-3 contracts as well as commercially.*

Product Information:

- *The secondary capability on the Antares ISS Resupply Missions is mass-flexible. Each Mission has a mass commitment for ISS cargo, however the ISS program can re-allocate secondary mass as ISS cargo mass*
- *Secondary environments match Antares payload launch environments depending on mounting scheme used*

Orbital ATK: Cygnus Service Module



Heritage / Schedule Information:

- *Orbital ATK Commercial ReSupply Missions launch several times each year. Four flights have successfully been completed and six more planned*
- *Orbit on Cygnus is ~400 km, Inclined 51.6°, but can be modified after Cygnus ISS departure*
- *Current Launch Schedule:*
  - *1Q 2017, 3Q 2017, 4Q 2017*
  - *2Q 2018, 4Q 2018*
- *Orbital ATK has been chosen for CRS-2 contract, with Launch Schedule to be determined*

Company Information:

- *Michael Bain, 832-415-1251, michael.bain@orbitalatk.com*
- *OrbitalATK.com*
- *Orbital ATK is based out of Dulles, Virginia and has major operating locations in 17 states. It has more than 12,000 employees and was established in 2015 in the merger of Alliant Techsystems and Orbital Sciences Corporation. Orbital ATK's satellites are available through the GSFC RSDO contract and commercially.*

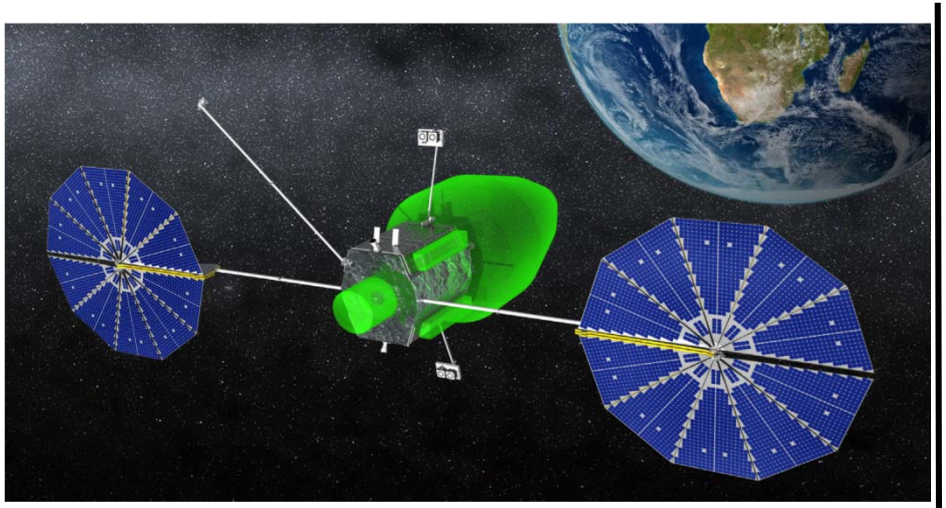
Product Information:

- *The total secondary mass capability on Cygnus for ISS Resupply Missions are mass-flexible. Each Mission has a mass commitment for ISS cargo, however the ISS program can re-allocate secondary mass as ISS cargo mass*
- *Ride Share locations are located on the Service Module, per figure above*

Orbital ATK: Rideshare Opportunities

- Antares (with Cygnus):
  - CubeSats Deployers
  - Payloads Smaller than ESPA (longer but skinnier), mass flexible
  - Orbit: 185x300 km, 51.6°
  - Antares without Cygnus:
    - ESPA Payloads - shorter than standard ESPA P/L (due to 3.9 M faring v. 4.3 M diameter)
- Cygnus:
  - CubeSats Deployers
  - Payloads less than 50 kg, custom shapes – see quad chart
  - ISS Orbit: ~400 km, 51.6° (post ISS: slightly above/below & different inclination)
- Launch Opportunities
  - Antares and Cygnus will launch several times a year through 2022 (3 possible launches in 2017).

Orbital ATK: GEO Hosted Payload



Heritage / Schedule Information:

- *Orbital ATK Mission Extension Vehicle (MEV) is planned for first flight in late 2018*
- *Orbit is GEO*
- *Lifetime is 15 years*
- *Mission: Rendezvous, Proximity Operations and Docking for commercial satellite servicing including:*
  - *Station keeping*
  - *Inclination reductions*
  - *Graveyarding*
  - *Flyby Inspections*

Company Information:

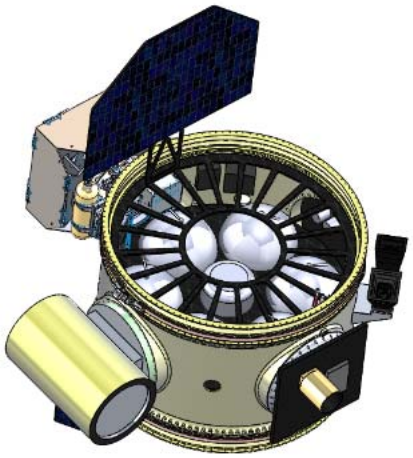
- *Joe Anderson, 703-948-8347, joseph.anderson@orbitalatk.com*
- *OrbitalATK.com*
- *Orbital ATK is based out of Dulles, Virginia and has major operating locations in 17 states. It has more than 12,000 employees and was established in 2015 in the merger of Alliant Techsystems and Orbital Sciences Corporation. The MEV is available through commercial contracting.*

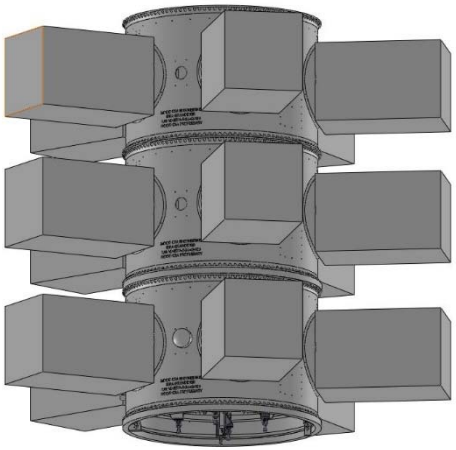
Product Information:

- *Hosting information*
  - *Hosted payload capacity is up to 1000 kg*
  - *Hosted payload power is 2 kW*
  - *Various volumes available on Nadir, aft, or side panels*
  - *Ride-share to Geo with or without separation/deployment*
  - *HP can temporarily be the primary mission*
- *More detailed information on the MEV is available at:*

http://www.orbitalatk.com/space-systems/human-space-advanced-systems/mission-extension-services/default.aspx

Moog - OMV





Heritage / Schedule Information:

- *OMV based on flight heritage ESPA Ring (example LCROSS mission)*
- *All other elements (avionics, propulsion, power, comm, GNC) are TRL 9 and many sourced from within Moog reducing cost and schedule*
- *Modular and scalable architecture to meet mission needs from short life commercial LEO tug to 5 year Class C operational mission beyond Earth Orbit*
- *Targeting first flight to LEO in late 2018*

Company Information:

- *Christopher Loghry, cloghry@moog.com*
- *720-289-7041 or 818-734-3445*
- *www.moog.com/space*

- *Moog is a $2.5B company with 11,000 employees in locations in 27 countries*
- *Moog is headquartered in East Aurora, NY and has Space locations all over the US*
- *Moog was founded in 1951 and has supported nearly every single major space program including Apollo, Space Shuttle, EELV, and ISS*

Product Information:

- *Orbital Maneuvering Vehicle (OMV) leverages Rideshare for low-cost access to space*
- *OMV provides standalone power, propulsion, avionics, and communication as Free Flyer*
- *OMV can be used to achieve optimal orbits of spacecraft or other payloads including Beyond Earth Orbit*
- *OMV can also act as a hosted payload platform for payloads and be part of a system architecture (e.g. Comm Relay in Hub & Spoke system)*

MOOG
SPACE AND DEFENSE GROUP

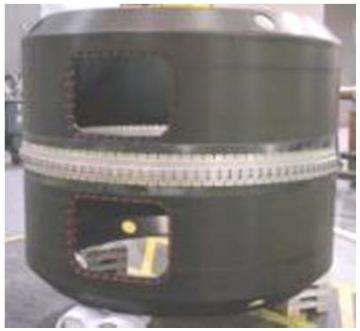
Example ESPA Configurations

ESPA P/N	# & Ø of Ports	ESPA Height	Port Payload	ESPA Mass	Notes
6-15-24	6 x 15”	24”	180 kg	136 kg	Standard ESPA
4-24-42	4 x 24”	42”	300 kg	211 kg	ESPA Grande
5-24-42	5 x 24”	42”	300 kg	212 kg	“SHERPA”
Other ESPA Configurations that have been designed and analyzed					
4-24-32	4 x 24”	32”	300 kg	170 kg	ESPA Midi
4-24-32	4 x 24”	32”	300 kg	133 kg	ESPA Midi ¼” Wall
4-24-60	4 x 24”	60”	300 kg	286 kg	Max Height ESPA
12-11.7-24	12 x 11.7”	24”	~85 kg	~136 kg	Multiple Small Sats

Secondary Payload Adapters

ESPA

Flat Plate Adapters



CASPAR

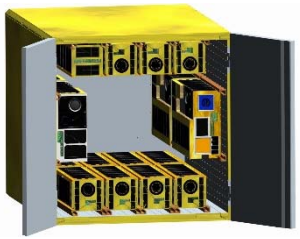
ESPA SUM

CubeStack Wafer

ESPA 6-15-24 LCROSS

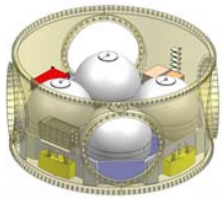
SL ESPA 15

SL ESPA 24

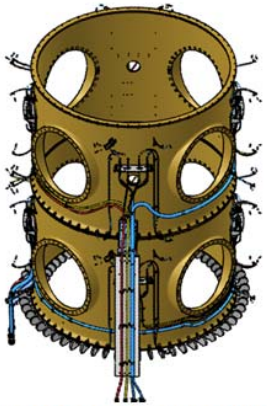


FANTM-RiDE

ESPA 4-15-24 DSX



ESPA 4-24-32 SPECIAL OMEGA



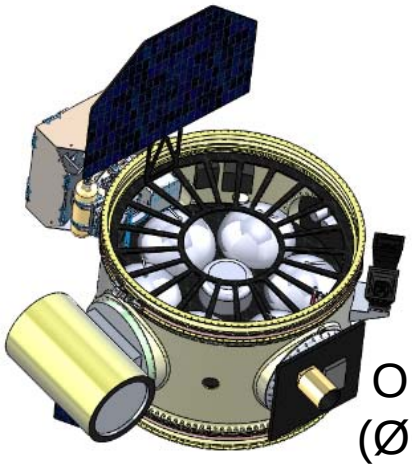
2x ESPA 4-24-42 ORBCOMM

Small Launch Adapter and SL-OMV (Ø38”)

ESPA 2-15-24-4PT EAGLE

ESPA 5-24-42 SHERPA

ESPA n-d-h
n=number of ports, d=port diameter (inches), h=ring height (inches)



OMV (Ø62”)